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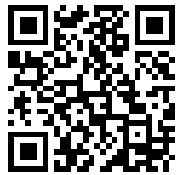

Transactions of the Canadian Society of Civil Engineers

Canadian Society of Civil Engineers

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TRANSACTIONS

of the

Canadian Society of Civil Engineers

VOL. XIX., PART I.

JANUARY TO JUNE,

1905.

Montreal:

PRINTED FOR THE SOCIETY

AT THE WITNESS PRINTING OFFICE,

1905.

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TRANSACTIONS

of the

Canadian Society of Civil Engineers

VOL. XIX., PART II.

OCTOBER TO DECEMBER

1905

Montreal:
PRINTED FOR THE SOCIETY
AT THE WITNESS PRESS.
1906

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INSTRUCTIONS FOR PREPARING PAPERS, ETC.

In writing papers, or discussions on papers, the use of the first person should be avoided.

They should be legibly written on foolscap paper, on one side only, with a margin on the left side.

Illustrations, when necessary, should be drawn on the dull side of tracing linen to as small a scale as is consistent with distinctness. They should not be more than ten inches in height and *in no case* should any one figure exceed this height. Black ink only should be used, and all lines, lettering, etc., must be clear and distinct.

When necessary to illustrate a paper for reading, diagrams must be furnished. These must be bold, distinct and clearly visible in detail for a distance of thirty feet.

Papers which have been read before other Societies, or have been published, cannot be read at meetings of this Society.

All communications must be forwarded to the Secretary of the Society from whom any further information may be obtained.

The attention of Members is called to By-Laws 46 and 47.

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The

Canadian Society of Civil Engineers.

877 DORCHESTER STREET, MONTREAL.

Established Feb. 24, 1887: Incorporated by Dominion Act, June 23rd, 1887.

(50 Vic., Cap. 124.)

Report of Annual Meeting

1905.

VOLUME XIX.

MONTREAL:
PRINTED FOR THE SOCIETY
AT THE WITNESS PRINTING HOUSE.

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Report of Proceedings

Annual General Meeting 24th January, 1905.

The meeting was called to order by the President, Col. W. P. Anderson, at 10.30 a.m.

The Secretary read the notice commencing the meeting and the minutes of the last Annual Meeting, 26th, 27th, and 28th of January, 1904.

The following gentlemen were nominated by the President as scrutineers of the ballots:—

For election of officers and members of Council:—Messrs. J. Ewing, W. J. Camp, C. S. Leech, N. H. Greene and W. D. Baillairgé.

For Nominating Committee:—J. M. Nelson, G. H. Dawson, and C. H. Ellacott.

For Amendments to By-laws:—L. G. Papineau, H. R. Lordly and Arthur Vincent.

The following reports of the Council, Treasurer and Library Committee were then read:—

REPORT OF COUNCIL FOR THE YEAR 1904

The Council begs to present the following report on the work of the Society during the past year:—

Roll of the Society.

The elections comprised nine members, twenty-seven Associate Members, five Associates and ninety-five Students; two members and two Associate Members have been re-instated; two members and one Student have been admitted to the Society under the Quebec Act; in all one hundred and forty-two. Seven Associate Members have been transferred to the class of Member, and twelve Students have been transferred to the class of Associate Member. Resignations have been received from five Members, three Associate Members, one Associate and three Students, in all eleven. There have been struck from the roll for non-payment of dues two Members, nine Associate Members, and one student; in all twelve. There have been twelve deaths: P. J. Lees Bolland, J. R. Perry and G. A. Simpson, Members; J. A. Duff, J. W. Fraser, J. D. A. Fitzpatrick, C. LeDuc, J. A. Marion, J. Spenard, Associate Members; C. F. Eicks, Associate; and B. O. Bay and S. H. Fillmore, Students.

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At present the membership stands as follows:—

	Res.	Non-Res.	Total.
Honorary Members	1	9	10
Members	63	323	386
Associate Members..	93	288	381
Associates	19	19	38
Students	150	287	437
Total			1252

At the same date last year:—

	Res.	Non-Res.	Total.
Honorary Members	2	8	10
Members..	72	306	378
Associate Members..	97	265	362
Associates..	16	19	35
Students	111	249	360
Total..			1145

At the present time there are pending thirty-seven applications for admission into the Society in the ordinary course.

The eighteenth Annual Meeting was called to order at 10.30 a.m. on Tuesday, 26th January, 1904, Mr. K. W. Blackwell, President, in the chair. The Report of Council for the year 1903 together with the statement of the Treasurer and the report of the Library Committee were presented to the meeting and adopted. At 1 p.m. there was an informal luncheon in the upstairs reading-room. At 3 p.m. the meeting re-assembled to hear an address by Dr. A. Stansfield on "Recent Developments in Electro-Metallurgy with especial Reference to Iron." At the evening session, Mr. M. J. Butler delivered an illustrated address upon "The Construction and Equipment of the Montreal Locomotive and Machine Company's Works" and was followed by Mr. H. Goldmark in an illustrated address on "The New Shops of the Canadian Pacific Railway Company at Montreal." On Wednesday, 27th January, the membership to the number of 200, visited the works of the Locomotive and Machine Company and were there entertained at luncheon. Afterwards the party visited the Shawinigan Water and Power Company's Transformer Station, and the new shops of the Canadian Pacific Railway Company. At 8 p.m., the members' dinner was held in the Windsor Hotel. There was an attendance of 80, exclusive of guests. On Thursday, 28th January, the meeting re-assembled for the transaction of business and to hear the address of the retiring President. At 4.30 p.m. the newly elected President, Colonel W. P. Anderson,

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and Mrs. Anderson, received the members and their friends in the Society's rooms.

Meetings.

There were seventeen meetings of the Society held during the year: five business meetings and twelve sectional meetings. The following papers were read:—

Electrical Section:—

"Some Problems in Storage Battery Engineering," by Dr. W. E. Winship.

"The Use of Electricity on the Lachine Canal," by L. A. Herdt, A. M. Can. Soc. C. E.

"Electrical Equipment for the Cornwall Canal," by F. H. Leonard, Jr.

General Section:—

"The Shubenacadie River Bridge," by J. J. Taylor, M. Can. Soc. C. E.

"Use of Rock and Mastic Asphalt in Bridge and Reservoir Construction," by H. Wiederhold.

"Experiments on Loss of Heat from Iron Pipes," by R. W. Leonard, M. Can. Soc. C. E.

"Bridge Launching," by B. J. Forrest, M. Can. Soc. C.E.

Mechanical Section:—

"Hydraulic Dredge, J. Israel Tarte," by A. W. Robinson, M. Can. Soc. C. E.

"Measurement of Water by a Venturi Meter, viewed from a New Standpoint," by R. Steckel, M. Can. Soc. C. E.

"Locomotive Crossheads," by W. F. Drysdale, S. Can. Soc. C.E.

Mining Section:—

"Methods of Mining and Timbering in Large Ore Bodies in British Columbia and Michigan," by N. W. Parlee, S. Can. Soc. C. E.

"Mine Timbering in Section 16 of the Lake Superior Mining Company, Michigan," by C. G. Campbell, S. Can. Soc. C. E.

Visit of Institution of Civil Engineers' Party.

A party of members of the Institution of Civil Engineers, accompanied by ladies, arrived in Montreal from New York on Monday, 19th September. The party included Sir William White, President, Dr. J. H. T. Tudsbery, Secretary, Messrs. C. A. Brereton, Alexander Ross and W. C. Unwin, F.R.S., Members of Council, 23 ladies 21 Members, 24 Associate Members, 3 Associates, and 21 Students and others; in all 97.

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On Tuesday, the party visited the shops of the Canadian Pacific Railway Company. They were entertained at luncheon by the Company, and were afterwards conveyed to points of interest in Montreal by street car and carriage. In the evening a reception was given to the visitors by the officers and members of the Society in the Society's rooms.

On Wednesday, an excursion was made through the Soulanges Canal and down the St. Lawrence. In the evening the Governors, Principal and Fellows of McGill University held a reception in honour of the party in the Macdonald Engineering Building. Leaving at midnight, the party was conveyed by special train over the Intercolonial Railway to Quebec, and on Thursday visited the various points of interest in and about Quebec, including the site of the new bridge and the electric installation at Montmorency Falls. Leaving Quebec at 10 p.m., a special train brought the party to Ottawa over the Intercolonial, Grand Trunk and Canada Atlantic Railways, arriving in Ottawa on Friday at 8 a.m.

At Ottawa, the visitors were received at the City Hall by the Mayor, and the local members of the Society entertained them at luncheon in the Victoria Hotel, Aylmer. Works of interest in Ottawa were visited, and in the afternoon, Mr. T. C. Keefer, C.M.G., Past President of the Society gave a Reception at his residence, the Rockcliffe Manor House. A complimentary train over the Canadian Pacific Railway conveyed the party to Montreal which was reached at 11 p.m.

On Saturday some of the members visited the works of the Shawinigan Water and Power Company and other works of engineering interest in Montreal and vicinity.

On Sunday a special complimentary train provided by the Grand Trunk Railway conveyed the party to Toronto.

On Monday, Toronto was seen from tallyhos, and private carriages, and the party was hospitably received by Mr. and Mrs. Nordheimer, at their residence. The members of the Society resident in Toronto entertained the visitors and some of the prominent residents of Toronto at luncheon in the King Edward Hotel. In the afternoon there was a steam yacht excursion on Lake Ontario, and the Lieutenant-Governor, the Hon. W. Mortimer Clark, and Mrs. Clark, gave a Reception in honour of the visitors. The Canada Foundry Company's works and other works of interest were visited by some members of the party.

On Tuesday morning, Niagara Falls was reached by Grand Trunk Railway, and the very important power works in progress on the Canadian side were carefully inspected. Luncheon was provided the party by the local members of the Society and the Entertainment Committee associated with them. In the afternoon some

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of the manufacturing industries on the American side were examined. In the evening the party took a special train by way of Hamilton and Port Huron to Chicago.

The special thanks of the Society are due to the Grand Trunk, Canadian Pacific, Intercolonial and Canada Atlantic Railways for free haulage of trains and other facilities placed at the disposal of the Society for the entertainment of the Institution party. To the Montreal Street Railway, the Quebec Harbour Commissioners, Quebec Railway Light and Power Company, Mr. T. C. Keefer, Ottawa, the Ottawa Street Railway, Mr. S. Nordheimer, Toronto, the several Power Companies at Niagara Falls, and the International Railway Company, Niagara, the special thanks of the Society are also due.

Gzowski Medal.

In accordance with the report of the Committee, the Gzowski Medal for the year 1903-4 has been awarded to Mr. J. A. Jamieson for his paper upon "The Pressure of Grain in Deep Bins."

Prizes for Students Papers.

The Examiners appointed for the reading of Students' papers have reported recommending the following as the best papers in the several sections:—

Electrical.—"An Investigation of a 16 K. W. Constant Current Transformer," by C. H. Wright.

Mining.—"The Centre Star Mine, Rossland, B.C.," by L. Heber Cole.

General.—"Port Colborne Harbour Works," by J. M. Hogan.

The awards have been made in accordance with this report. The Examiner for the Mechanical section has reported that none of the papers submitted to him were of sufficient merit to justify recommendation for a prize.

Branch Societies.

Acting on the Resolution of the last Annual Meeting, viz.:— "That the Council be instructed to consider with as little delay as possible the establishment of branches of this Society in the larger centres in Canada, and be authorized to provide the financial aid necessary to establish and maintain such branches," a Committee has been actively engaged in the formation of a branch of the Society in Toronto during the past few months. There is good reason to believe that a vigorous branch of the Society will be formed there.

The Council has under consideration a scheme for rendering the Society's Library available to non-resident members. It also es-

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pecially commends the extension of the usefulness of the Society by assisting in the establishment of the nuclei of Libraries at such centres as branches may be established. Further reference to this important matter is made in the Library report.

GENERAL.

In view of the Report of the Secretary that owing to the very great increase in the clerical work of the office, arising from the growth of the Society, and its importance as a National Institution, additional provision should be made for the carrying out of the secretarial duties, the Council has, after very mature consideration, submitted to the membership a ballot embodying its views as to the method by which this provision should be made.

Owing to the necessity of having a representative of Mining Engineering amongst the resident members of Council, Mr. C. B. Smith resigned his position as Councillor, and Dr. J. B. Porter was appointed to fill the vacancy thus created.

In accordance with By-law 28*a* the following were, at the first meeting of Council held after the last Annual Meeting, appointed officers of Sections to hold office from 1st June, 1904, to 1st June, 1905.

General:—D. Macpherson, President; C. H. Keefer, Vice-President.
Electrical:—R. B. Owens, President; W. McLea Walbank, Vice-President.
Mechanical:—Phelps Johnson, President; M. J. Butler, Vice-President.
Mining:—J. B. Porter, President; K. W. Blackwell, Vice-President.

In obedience to the resolution passed at the last Annual Meeting:—"That the Council be requested to consider an amendment to By-laws having in view the election of a President from amongst the Vice-Presidents of the previous year," careful enquiry was made and it was found that in the history of the Society to date, this rule had been practically observed, and in view of this fact, it was not thought desirable to propose an amendment to by-laws as suggested at the present time.

The attention of Council has been called to the importance of special enquiry into a general system of engineering standards for Canada, and the appointment of a Standards Committee is recommended to report upon the matter in conjunction with similar Committees of other National Societies.

W. P. ANDERSON,
President.

C. H. McLEOD,
Secretary.

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Treasurer's Report for the Year 1904.

The finances of the Society still continue to be in a satisfactory condition.

The receipts last year were $1,126.00 less than those for 1903.

The arrears of fees received during 1904 were $728.00 less than the arrears received during the previous year, and the remainder of the deficiency, amounting to about $400.00, is distributed over the other items.

It is hoped that the arrears of fees will be well paid up during the present year, now that there is such a demand for all branches of Civil Engineers, at a much better rate of remuneration that has previously obtained. The total expenditure for 1904 appears at first sight to be much smaller than that for 1903. That is due, however, to including the balance of mortgage, amounting to nearly $1,250.00, in the ordinary expenditure for 1903, instead of charging it to capital account. As our books are now being kept in a more detailed manner, our Auditors, Messrs. Riddell and Common, have arranged the annual statement so as to show the expenditure on Revenue Account separate from that on Capital Account.

The regular expenditure for 1903 was about the same as that for 1904, or about an average of $5,500.00, being about $1,000.00 less than the receipts from fees.

If, therefore, we increase our ordinary expenditure on account of the Secretary's office by the amount of say $1,000.00 per annum, it will be necessary for all members to pay their fees promptly.

I have to thank the members of the Finance Committee, and more particularly the Chairman, Mr. Walbank, for their assistance during the year in attending committee meetings, and I am also much indebted to the Auditors, Messrs. Riddell and Common, for advice as to the manner of keeping our books.

H. IRWIN,
Treasurer.

Montreal,
January 17th, 1905.

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CANADIAN SOCIETY OF CIVIL ENGINEERS—GENERAL FUND.

ABSTRACT OF RECEIPTS AND EXPENDITURES FOR THE YEAR ENDING 31ST DECEMBER, 1903.

Balance from 31st December, 1902		$1,024 06

GENERAL RECEIPTS.

Subscriptions :—		
Arrears	$1,859 50	
Current	4,176 00	
Advance	198 50	
Entrance fees	1,150 00	
	$7,384 00	
Transactions sold	32 50	
Dividend Can. Per. & Wes. Can. Mor. Co.	10 80	
Bank interest on current account	58 84	
Receipts from rent of bedrooms	121 10	
Refund on binding account	94 80	
Proceeds of sale of periodicals	29 10	
Mirror sold	15 00	
Life membership fee	150 00	
		7,896 14
		$8,920 20

GENERAL EXPENDITURE.

Transactions and advance proofs	$ 1119 22	
Printing, stationery, binding & diplomas	1019 39	
Books, magazines and library expenses.	144 68	
Postage, post cards and telegrams	340 50	
Cabs, carters, streetcars and messengers	28 50	
Examiners' fees and expenses	100 57	
Secretary's salary	300 00	
Teasurer's Salary	150 00	
Assistant Secretary's salary	550 00	
Caretaker's wages	410 00	
Interest on mortgage and notary's fees.	106 35	
Telephone service and repairs	38 75	
Bank commission on cheques	9 89	
Property and school tax	143 75	
Water rates	29 10	
Electric light	123 81	
Gas for cooking	23 80	
Coal and kindling wood	106 77	
Furniture and permanent fittings	72 87	
Repairs and house supplies	78 71	
Gzowski medal and engrossing	8 46	
Expenses during Annual Meeting	137 00	
Expenses at ordinary meetings	44 05	
Expenses *re* Summer Convention of 1902	16 00	
Legislation Expenses at Ottawa	35 75	
Auditors' fees	35 00	
Students' prizes	75 00	
Balance of Mortgage paid to Miss Greenshields	1,247 68	
New Century Typewriter	113 00	
Fire Insurance	68 00	
Miscellaneous	5 75	
		$6,682 35
Balance in Bank	$2,216 69	
Balance from Assistant Secretary	21 16	
Total Balance on hand		$2,237 85
		$8,920 20

H. IRWIN, *Treasurer*,

Verified, RIDDELL & COMMON, *Auditors*.

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Subscriptions:—		
Arrears	$1,131 00	
Current	4,311 00	
Advance	237 00	
Entrance fees	840 00	
		$6,519 00
Rent of Bed Rooms		101 70
Dividends, etc.:		
Can. Per. & West. Can. Mtg. Co. Stock	10 80	
Montreal Light, Heat & Power Co.	6 00	
Interest on Svgs. Bank acct.	83 37	
" " overdue Fees	17 55	100 92
		117 72
Student's Exam. Fee under Que. Act		20 00
Transactions sold		11 50
Total Receipts		6,769 92
Cash Balance from 31st December, 1903		2,237 85
		$9,007 77

H. IRWIN, *Treasurer.*

17th January, 1905.

Transactions and advance proofs	$1,470 35	
Printing, stationery, binding and diplomas	593 03	
	5 80	
Less refund		587 23
Books, magazines and library expenses		56 02
Postage, post cards and telegrams		371 47
Cabs, carters, messengers, etc		41 76
Examination fees and expenses		60 00
Secretary's salary		300 00
Assistant Secretary's salary		600 00
Caretaker's wages		420 00
Telephone		48 18
Bank commission on cheques		9 97
Insurance		10 00
Property and school tax		161 00
Water rates		45 59
Electric light		144 14
Gas for cooking		23 20
Coal and wood		131 37
Repairs and house supplies		107 60
Gzowski medal and engrossing		8 10
Expenses at ordinary meetings		119 85
Expenses during Annual Meeting		244 40
Legislation Expenses:		
Dominion	62 00	
Quebec	40 30	
Manitoba	5 00	
		107 30
Auditors' fees		35 00
Students' prizes		85 00
Expenses re visit of Institute of C. E.		68 00
Miscellaneous Expenses		66 40
Total expenditure on Revenue acct		5,322 53
Furniture and permanent fittings	273 93	
Proportion life membership fee received in 1903, invested in Mtl. Light, Heat & Power Co. stock	140 50	
Total expenditure on Capital acct.		414 43
Total expenditure		5,736 96
Balance in bank	3,238 84	
Cash from Asst. Secretary	31 97	
		3,270 81
		$9,007 77

Verified, RIDDELL & COMMON,

Auditors.

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CANADIAN SOCIETY OF CIVIL ENGINEERS.

STATEMENT OF ASSETS AND LIABILITIES AT 31st DECEMBER, 1903.

LIABILITIES.		ASSETS.	
Nil.		Property, No. 877 Dorchester Street, Cost less 3 per cent for depreciation	$16,835 34
		Furniture, as per Inventory	1,957 75
		Books—estimated value	4,000 00
		Arrears of Fees	2,000 00
		Canada Permanent & Western Canada Mortgage Corporation Stock	180 00
		Cash on hand	2,237 85
		Gold Medal	45 00
Surplus of Assets over Liabilities	$27,255 94		
	$27,255 94		$27,255 94

H. IRWIN,
Treasurer.
19th January, 1904.

Certified abstract of statement verified by us,
RIDDELL & COMMON,
Auditors.

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STATEMENT OF ASSETS AND LIABILITIES AT 31st DECEMBER, 1904.

Liabilities.			*Assets.*		
Nil.			Property No. 877 Dorchester street		
Surplus at 31st Dec., 1903	27,255 94		Balance at 31st December, 1903.....	16,835 34	
Add receipts on revenue acct. 1904,	6,769 92		Less 1 per cent. of cost price written off for depreciation.....	170 00	
Less expenditure " " "	5,322 53				16,665 34
	1,447 39		Furniture—Balance at 31st Dec., 1903...	1,957 75	
Estimated value of additions to Library during year as per inventory.....	200 00		Less 10 per cent. written off for depreciation	195 77	
		28,903 33		1771 98	
Less written off for depreciation—			Add cost of additions during year	273 93	
Property acct.	170 00				2,035 91
Furniture	195 77		Books—balance at 31st Dec , 1903.....	4,000 00	
	365 77		Estimated value of additions during year as per inventory at 21st Dec., 1904... .	200 00	4,200 00
Written off arrears of fees.....	150 00	515 77	Arrears of Fees—estimated value at 31st Dec. 1904		1,850 00
Surplus of Assets over Liabilities 31st Dec., 1904.....		28,387 56	Canada Permanent & Western Canada Mortgage Corporation Stock.....		180 00
			Montreal Light Heat and Power Co. Stock		140 50
			Gold Medal		45 00
			Cash in Bank.....	3,238 84	
			Cash on hand	31 97	3,270 81
		$28,387 56			$28,387 56

H. IRWIN,
Treasurer.
17th January, 1905.

Verified,
RIDDELL & COMMON,
Auditors.

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Report of the Library Committee.

At the last Annual Meeting, the Council was instructed to take measures to add to the Library and to collect and index the trade catalogues of the more important manufacturers of engineering machinery and supplies.

Acting on these instructions, committees of the several sections were appointed to aid the Library Committee in preparing a list of the additional books needed to give the Society a good working Library. This list has been prepared and revised, and at the Council meeting held on 10th instant, the sum of $600.00 was appropriated for the purchase and cataloguing of the most desirable of the books recommended. As soon as these books are received, a catalogue of them, and of all other modern books and periodicals in the Library, will be prepared and sent out to members.

The collection of trade catalogues suggested at the last Annual Meeting is nearly completed. The publications of over 400 engineering firms, amounting to a total of about 1,800 books and pamphlets, have been secured and placed in cases in a special room in the basement. A card index of these catalogues, arranged by subjects and firms, is in preparation, and the room will soon be thrown open to members. The system of filing and indexing these catalogues is such that additions and renewals can be easily and quickly entered and rendered available.

In connection with the work of cataloguing the library a small collection of library catalogues and bibliographies, and the engineering index to current periodicals, are being placed where they can be consulted. From these, references can readily be made to books and periodicals in our own and other libraries.

Several plans have been considered for rendering the Library of greater use to non-resident members, and it is hoped that a satisfactory scheme may soon be formulated. In the meanwhile arrangements have been made whereby members can have references looked up and articles copied or abstracted by competent persons at a cost not to exceed 60 cents per hour. Similar arrangements are also proposed in connection with the use of the bibliographies for out of town members.

During the year the following works have been presented to the Library. These, with the volumes now on order, will be catalogued as soon as the complete list can be prepared.

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Bound Volumes.

Altitudes in Canada, Jas. White, Ottawa.

Location and Examination of Magnetic Ore Deposits—E. Haanel Supt. of Mines, Ottawa.

Report of Metropolitan Water and Sewerage Board, Boston, Mass.

Geological Survey of Ohio, Bulletins 1 and 2.

Electricity and Matter, by Thomson.—Presented by H. Walker, S.C.S.C.E.

Pamphlets.

1. Report of City Engineer, Halifax, N.S., F. W. W. Doane.
2. Catalogue of Murray Iron Works, F. W. Salmon.
3. Report of Province of Quebec Rifle Association, 1903.
4. Railway Statistics, Dom. Canada, from C. Schreiber.
5. Bacterial Treatment of Sewage, E. Mohun.
6. Report, Dept. Railways and Canals, Canada, C. Schreiber.
7. The Currents on the South Eastern Coasts of Newfoundland, W. Bell Dawson.
8. Year Book, Armour Inst. of Technology.
9. Annual Report City Engineer, Providence, R.I.

Magazines.

Cantor Lectures on the Mining of Non-Metallic Minerals, by Bennett H. Brough.

The following is a complete list of the periodicals, magazines, transactions, etc., regularly received and on file in the library.

*American Society of Civil Engineers, Transactions, *New York.*

*American Society of Mechanical Engineers, Transactions, *New York.*

*American Institute of Electrical Engineers, Transactions, *New York.*

*American Institute of Mining Engineers, Transactions, *Philadelphia.*

American Architect and Building News, *Boston.*

American Engineer and R.R. Journal, *New York.*

American Railway Engineering, *Chicago.*

American Water Works Association.—Proceedings.

"Antonio Alzate" Scientific Society, Transactions, *Mexico.*

Association of Industrial Engineers, Transactions, *Barcelona.*

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Association of Engineering Societies, Transactions, *New York.*

Boston Public Library, Bulletin, *Boston.*

Bulletin of Public Works, *Buenos Ayres.*

Bureau of Mines, Reports, *Toronto.*

Bibliographie des Sciences et de l'Industrie, *Paris.*

Canadian Engineer, *Toronto.*

*Canadian Institute, Transactions, *Toronto.*

†Canadian Magazine, *Toronto.*

Canadian Mining Institute, *Montreal.*

Cassier's Magazine, *New York.*

†Century, The, *New York.*

†Chambèrs' Journal, *London.*

*Cleveland Institute of Engineers, Transactions, *Middlesborough.*

Colorado School of Mines, *Golden, Col.*

Department of Trade and Commerce, *Ottawa.*

Department of Railways and Canals, *Ottawa.*

Department of the Interior, *Ottawa.*

Domestic Engineering, *Chicago.*

Electrical Engineer, *London.*

Electrical News, *Toronto.*

Electrical Review, *New York.*

Electrical Review, *London.*

*Engineers' Club of Philadelphia, Proceedings, *Philadelphia.*

*Engineers' Association of New South Wales, Transactions, *Sydney.*

Engineering Association of the South, Transactions, *Nashville, Tenn.*

Engineers' Association of Western Pennsylvania, Transactions, *Alleghany, Pa.*

*Engineering News, *New York.*

Engineering and Mining Journal, *New York.*

Engineer, *Chicago.*

†*Engineer, *London.*

*Engineering, *London.*

Engineering Magazine, *New York.*

*Engineering Record, *New York.*

Engineering Review, *London.*

Engineering Times, *London.*

*Franklin Institute, Journal of, *Philadelphia.*

Geological Survey of Canada, Reports of, *Ottawa.*

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Hanover Architects' and Engineers' Society, Transactions, *Hanover.*

†Harper's Monthly.

Hungarian Society of Civil Engineers, Transactions, *Buda-Pesth.*

†Illustrated London News, *New York.*

Ingénieur, *Paris.*

*Institution of Civil Engineers, Transactions, *London.*

*Institution of Mechanical Engineers, Transactions, *London.*

*Institution of Electrical Engineers, Transactions, *London.*

†Iron Age, *New York.*

Iron and Machinery World, *Chicago.*

*Iron and Steel Institute, Transactions, *London.*

Iron and Steel, *Chicago.*

Iron World, *Chicago.*

Indian Engineering, *Calcutta.*

Institute of Mining and Metallurgy, *London, Eng.*

*Institution of Engineers and Shipbuilders in Scotland, Transactions, *Glasgow.*

*Junior Engineering Society, Transactions, *London.*

Journal of the U.S. Artillery, *Fort Monroe, Va.*

La Revue Technique, *Paris.*

Lake Superior Mining Institute, *Ishpeming.*

*Liverpool Engineering Society, Transactions, *Liverpool.*

Locomotive Engineering, *New York.*

London Magazine, *London.*

Machinery, *New York.*

Marine Review, *Cleveland, Ohio.*

*Marseilles Scientific and Industrial Society, Transactions, *Marseilles.*

*Manchester Association of Engineers, Transactions, *Manchester.*

†McClure's Magazine, *New York.*

Mechanical Engineer, *Manchester.*

Midland Institute of Civil, Mechanical and Mining Engineers, Transactions, *Barnsley.*

Mines and Minerals, *Scranton.*

*Mining Institute of Scotland, Transactions, *Hamilton.*

Mining Reporter, *Denver.*

Mining Society of Nova Scotia, Transactions, *Halifax.*

Monthly Weather Review, *Washington.*

Municipal Engineering, *Indianapolis.*

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North of England Institute of Mining and Mechanical Engineers, *Newcastle-on-Tyne, Eng.*

North of France Industrial Society, Transactions, *Lille.*

Nova Scotian Institute of Science, Transactions, *Halifax.*

North East Coast Institution of Engineers and Shipbuilders, Transactions, *Newcastle.*

†Outing, *London.*

Ottawa Literary and Scientific Society, *Ottawa.*

†Page's Magazine, *London.*

Patent Office Library, Reports of, *London.*

*Philosophical Society of Glasgow, Transactions, *Glasgow.*

Pocket List of Railroad Officials.

†Punch, *London.*

Public Works, Province Quebec, *Quebec.*

Practical Engineer, *London.*

Public Works Department, *Buenos Ayres.*

Railway and Engineering Review, *Chicago.*

Railroad Gazette, *New York.*

Railway Age, *Chicago.*

Railway and Shipping World, *Toronto.*

Report of Chief of Engineers, U. S. Army, *Washington.*

Revue Technique, *Paris.*

Royal Artillery Institution, Transactions, *Woolwich.*

Royal Society of Canada, Transactions, *Ottawa.*

Royal Engineers' Institute, Transactions, *Chatham, Eng.*

Royal Institute of British Architects, Transactions, *London.*

Royal United Service Institution, Transactions, *London.*

Royal Dublin Society, Transactions, *Dublin.*

*Royal Society of Edinburgh, Transactions, *Edinburgh.*

Royal Scottish Society of Arts, Transactions, *Edinburgh.*

Royal Institute of Engineers, Transactions, *The Hague.*

Royal Irish Academy, Transactions, *Dublin.*

Sanitarian, *Brooklyn, N. Y.*

School of Mines, Quarterly, *New York.*

*Society of Engineers, Transactions, *London.*

*South Wales Institute of Engineers, Transactions, *Merthyr Tydvil.*

*Society of Civil Engineers, Transactions, *Paris.*

Society of Arts, Transactions, *London.*

School of Practical Science, *Toronto.*

Statistical Year Book of Canada, *Ottawa.*

†Strand Magazine, *London.*

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†Sketch, *London.*

†Scribner's, *New York.*

Technical Society of the Pacific Coast, Transactions, *San Francisco.*

Telephone Magazine, *Chicago.*

Technology Quarterly, *Boston.*

Bulletin University of Washington Library, *Seattle, Wash.*

University Chronicle, *Berkeley, Cal.*

U. S. Naval Institute, Transactions, *Annapolis.*

U. S. Geological Survey Reports, *Washington, D. C.*

Vienna Society of Engineers and Architects, *Vienna.*

Western Railway Club, Transactions, *Chicago.*

Western Society of Engineers, Transactions, *Chicago.*

Western Electrician, *Chicago.*

Wisconsin University, Bulletin of, *Madison, Wis.*

†Windsor Magazine, *London.*

Those marked † are paid for; all the others are exchanges.

Those marked * are bound at the end of each year, and placed on the shelves in the General Reading Room.

P. W. ST. GEORGE,
Chairman.

E. G. M. CAPE,
Librarian.

Upon motion by Mr. J. Kennedy, seconded by Mr. C. H. Keefer, the reports were received.

Mr. H. R. Lordly called attention to the agreement of members under Form D. wherein it is specified that members shall present to the Society "an original communication, a drawing, plan or model of engineering interest, or some scientific work for the Library" and suggested that all should be required to fulfill this agreement. On motion by Mr. R. B. Rogers, seconded by Mr. H. Irwin, it was unanimously agreed to recommend to Council that a list of books urgently required be sent to members.

Mr. Irwin read certain letters from outside members in regard to the relations of the Society to non-residents, and referred the members to the resolution adopted at the last Annual Meeting. He again urged the importance of establishing Libraries in connection with branches of the Society at local centres, and the adoption of means whereby the Library at head-quarters might be made more useful to non-residents, thus keeping the outside mem-

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bers more closely in touch with the Society. The non-resident members, he thought, had it in their own power to make the Society useful to them.

The President was of opinion that the gentlemen referred to took too narrow a view of their privileges, and stated that, in his opinion, it was a most fortunate circumstance that the headquarters of the Society had been established at Montreal.

The discussion was also taken part in by Messrs. R. B. Rogers and W. McLea Walbank, who concurred in the sentiments expressed by the President, but were also of opinion that everything possible should be done to extend the usefulness of the Library to the membership generally.

Further discussion of the Council Report was postponed until Thursday afternoon, in order to give members who had not yet arrived an opportunity of taking part therein.

A letter was read from the John McDougall Caledonia Iron Works inviting the members of the Society to visit the test of a Turbine Pump at their works.

The meeting then adjourned.

At 1.00 p.m., luncheon was served in the upstairs reading room to about 50 members.

Tuesday Evening, January 24th.

The meeting re-assembled at 8.00 p.m., at which the following address of the retiring President, Colonel W. P. Anderson, was read:—

PRESIDENT'S ADDRESS.

By Wm. P. Anderson.

At the end of my year of office as your President, I desire once more to thank you for the honour you conferred upon me by electing me to that position; the highest to which any Canadian engineer can aspire. As engineers we have good reason to feel proud of our past achievements, and by them we know that we are justified in looking forward confidently to a brilliant future. This splendid young country owes much to those members of our profession who developed its network of railways, its system of canals, its public works, in mining machinery, and its mechanical and electrical installations. With increased population and resources, the demand for further railway and industrial extension is rapidly growing greater and more urgent.

My attention was especially drawn to the magnitude of our achievements in engineering by noticing the strong impression

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made on those distinguished gentlemen, members of the parent engineering society, whom we lately had the pleasure of receiving amongst us.

This visit to Canada, in September last, of the President and a representation of the members of the Institution of Civil Engineers was one of the most notable events in our annals. We were delighted to be the hosts of a body of men so eminent in our common profession, on their first excursion outside the mother country, under the leadership of a President so talented, so genial and so eloquent as Sir William White. We were also pleased to know that the good opinion we formed of them was reciprocated. Under the auspices of this Society our visitors were shown a few of the engineering works between Quebec and Niagara, and given an opportunity of learning something of our present practice and our intentions for the future. They saw what we had been able to do with the small resources at our command, and they recognized the great promise that Canada holds out for engineering enterprise. We hope that their visit may have the effect of attracting some of the capital that is so badly needed, and that will reap so rich a harvest in the development of our inexhaustible natural resources.

I would take this opportunity of expressing to the several local committees in charge of the reception of the English engineers my congratulations on the thoroughness with which they accomplished their work, and convey to them the thanks of the Council and myself for their cordial co-operation in the entertainment of our guests.

Our visitors appeared specially interested in the great development of electrical energy which we have achieved, and which has already placed Canada second only to the United States in the total horse power used. They were likewise impressed with the possibilities for future advances in the same direction. The three great plants under construction at Niagara naturally aroused their greatest interest. It is questionable whether we, who live amongst these forces of nature, fully appreciate our priviliges as citizens of a country containing such abundant and inexhaustible water powers. To take one instance alone, that naturally present itself to me as a resident of Ottawa: within thirty miles of the Capital there is sufficient power going to waste to run all the mills and factories on this Continent, only awaiting the enterprise of man to be harnessed to his use. As a recent English writer points out, we are not, in utilizing water power, drawing on capital account, as England is obliged to do by her serious consumption of her coal deposits for power production.

The completion of the Georgian Bay canal, now reasonably

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probable, besides being in itself a noteworthy engineering feat, will open up another district abounding in water powers and capable through their utilization of infinite mineral and industrial development.

A further source of prospective riches to Canada is the plentiful presence of the constituents of Portland cement, in places convenient of shipment. The substitution of concrete for wood in structural work, especially for wharves, piers, and buildings liable to rapid deterioration by alternate wetting and drying, is coming to the front more prominently every year. It is needless to insist here on the superiority of concrete over timberwork, but it is surprising how widely the habit of using timber in wharves still persists in Canada. In the early days of the country, when money was scarce and timber plentiful, masonry expensive, and skilled labourers difficult to secure, it was only natural that timber structures should be used. It was at that time profitable to employ timber for such works, because the first cost was so reasonable that they could be repaired and replaced for less than the interest and sinking fund on the cost of more solid structures, but now that cement has become plentiful, good, and cheap, and especially during the last two or three years, when the price of lumber has very largely increased, and it is impossible to secure wood of the same quality as that used twenty years ago, it is little less than a crime to continue the construction of wooden wharves. There are circumstances under which timber can still be used to advantage in cribwork foundations under water, where its employment obviates the use of caissons or of costly diving operations, but in any other situation concrete will cost very little more in the first place, while its permanent nature will materially reduce charges for maintenance and repairs. The splendid quality of Portland cement now made by several Canadian manufacturers supplies an additional argument in favour of its universal adoption.

Our Society has prepared a general specification for Portland cement, which meets with the approval of engineers using that product. It is desirable that our members should keep this specification in mind, both to adopt it in their own practice, and also to suggest changes and improvements, as their individual experiences and the development of the industry may require.

We do not appear to have reached finality in the process of cement manufacture. The advantages claimed for silica cement are worthy of attention, and the claims lately put forward for slag cement will, if endorsed by experiment, lead to still further cheapening of concrete construction. The reinforcement of concrete structures by the inclusion of steel in their members is becoming widely practised, but it is to be feared that a great deal of steel

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so used has not been disposed in such a manner as to give the best results, and we have yet to learn how the permanence of such structures may be affected through the corrosion of the steel within the concrete. The question of the best method of shaping, connecting, protecting and placing the reinforcing steel requires more attention than it has yet received. Papers on this subject, and particularly papers describing the failure of any concrete or reinforced concrete design, if such were procurable, would be of great value to the Society.

Concrete is now largely used in Canada to replace the more expensive cut stone previously used in heavy foundations, in bridge abutments, etc. A great many piers, abutments and culverts have been built in concrete on the Canada Atlantic and other railways; and illustrations will occur to every member, of works in which concrete has been used in place of masonry with most satisfactory results. This applies particularly to a country in which masons or skilled labourers of any kind are scarce and expensive, and the resultant quality of masonry questionable.

Quite lately the industry has been begun of moulding building blocks from cement, and working them into buildings as ashlar masonry. This use of one material to simulate another, though perhaps commercially successful, rather grates on one's aesthetic sense. The Department of Public Works is now experimenting with reinforced concrete beams for pier construction, laid and connected like timbers. Such a plan appears to forfeit the advantage of mass gained by the usual practice of laying concrete in large blocks, and at best is only adapted to locations in which it would be difficult to deposit concrete in bulk.

The most important event of the year in Canada, from an engineering point of view, has been the inception of another transcontinental railway.

In view of the immediate and wonderful success that attended the completion of the C.P.R., and the mighty effect that it has had on the development of the Western and Northwestern portions of our country, it is not surprising that Canada undertakes the construction of this new road with feelings of greater confidence than existed when the Canadian Pacific scheme was submitted to the public. The new line will open up a country in parts hitherto inaccessible, and cheering reports respecting its fertility, its forest and mineral wealth, the easy gradients obtainable, and the light character of work required, have already been received. Members of our Society are now engaged in large numbers in the preliminary work of location, and this great national undertaking will for many years to come create a demand for the services of engineers of all grades, that cannot but be stimulating to our profession. In this connec-

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tion casual reference may be made to the complaints entered against the Grand Trunk Railway Company for the employment on their surveys of alien engineers. While it is quite proper for Canadian engineers, as individuals, to claim preference in employment on purely Canadian works, and while the Government should be expected to restrict to citizens employment by the Government, or by lines which it subsidizes, in accordance with the practice in other countries, yet it would be improper for a national society of engineers to take up a narrow position in dealing with engineering work. This Society has. therefore. not interfered, but has properly decided that the question was one for settlement between the company concerned and the Government, and it has adopted the catholic policy of welcoming to its ranks qualified practitioners, without respect to nationality. Notwithstanding this, however, it is an important function of this Society to advise the Government as to the qualifications of the engineers who should be employed on works, either directly or indirectly of a national character, and one of which the Government should not be slow to avail itself. It was gratifying to find that the General Manager of the Grand Trunk Railway recognized the status of this Society as being the final arbiter of the fitness of the engineers employed on their works of construction. This speaks well for the eminence our Society has attained within eighteen years of its organization, and proves that the high standards and conservative policy aimed at have secured the confidence of the public.

During the year the several sections which were authorized at our last annual meeting have been fully organized, and papers have been discussed by the branches to which they specially belonged. The decision to broaden our methods so as to draw closer together members of each of the divisions of engineering, into which modern conditions have tended to specialize the profession, has met with success. It is obviously preferable to have our electrical, mechanical and mining brethren members of one large society with common interests and federated strength, than to have separate and independent organizations. Another reason favouring this joint work is the difficulty of drawing distinctly the lines between the several classes of work; the mechanical engineer must to-day be an electrician, and the mining engineer needs the experience of the general civil practitioner. It would be a mistake to encourage the foundation of separate societies for the several branches. If any objections exist to the general policy of our Society, the proper course is to bring them up in our own body and be governed by the decision of the majority, rather than to form new organizations. Our council has abundantly shown its readiness to discuss reforms in the direction of extending our usefulness. That this policy has

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been successful is attested by our balance-sheet and by the fact that the very creditable home which we occupy has been acquired without any difficulty in meeting the extra expense. Much credit is due to the successive councils of the Society, and particularly to the members resident at headquarters, for the broad-minded and progressive policy they have pursued with such beneficial results, and the indefatigable work of the Secretary and other officers also merits the highest consideration of all members, and has been of the utmost assistance to your President.

The Society should look forward to increasing, at no distant day, the number of its working rooms, and, without usurping the functions of a social club, offer our members further accommodation. The very considerable use made of the two bedrooms already established warrant us in expecting that our members would welcome the addition of further accommodation for lodging and recreation, as well as for technical work.

A subject that appears to demand the immediate attention of the Society is the advocacy of the establishment of some central bureau for the registration of plans of all surveys made in Canada. It may be argued that this is a matter pertaining more closely to the provincial associations of land surveyors than to a society of engineers, but our members will acknowledge that the basis of all engineering work is accurate preliminary surveys, and when plans of such surveys are available a great deal of valuable time can be saved, and the necessity for duplicating work obviated. At the present moment, amongst the Dominion Government Departments, those of Public Works, Railways and Canals, Marine and Fisheries, Interior, Indian Affairs, Militia, Post Office, Geological Survey, and probably others, are all engaged in land and hydrographic surveying and mapping. The work done in one Department is not recorded in any way by which it can be made available for use by other departments, and, in numberless cases, surveys of the same locality have been made over and over again, and several plans of the same district or harbour are lying amongst old records, of no possible use to the public or the profession. It appears to be entirely feasible to have a regulation adopted by which plans of all surveys made could be registered in the care of one office, so that any one in Canada could obtain the best plan extant of any district required. In such a bureau there should be registered not only plans of the Dominion Government surveys, but also copies of plans made by the several provincial departments, and by Railway Companies and other large corporations undertaking surveying and engineering work throughout the Dominion.

Cognate to this question of the registration of plans is the larger question of better surveys of the whole Dominion of Canada;

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work heretofore done has not been based upon any general comprehensive scheme, but has been undertaken merely to meet exigencies as they arose. Canada has now surely grown sufficiently large and important to warrant the adoption of a national scheme of survey connecting the whole country geodetically. The land surveys made in the older provinces are all compass work, and are so glaringly inaccurate that any attempt to compile separate surveys into one map is heart-breakingly impossible. Those made of recent years under the control of the Department of the Interior are transit work, excellent in conception and execution, but there exists no comprehensive system of geodetic triangulation connecting the different districts. This matter of a main triangulation system is one that could appropriately be considered by this Society. It has engaged the attention of the Royal Society of Canada, and memorials have been presented to the Dominion Government in connection therewith, but up to date nothing definite has been done to carry it into execution. The obvious desideratum is a system of main triangulation continued northward, in the vicinity of the Winnipeg meridian, from the north and south triangulation of the United States Coast and Geodetic Survey, with branches carried east and west, across the continent, from this trunk, tying into the United States triangulation system already in existence. Under whose auspices this work should be done is a moot point; whether it should be undertaken by the Department of the Interior, with their existing surveying staff, whether it should be done, as in England, as an ordnance survey, under the military authorities, or under the direction of a separate organization, independent of existing departments, is for the Government to determine, but the necessity for beginning the work and having the results placed where they can be utilized, is becoming every day more apparent.

While on the subject of surveys, the opportunity seems apropos of again reminding our members of the importance of fixing and recording all main triangulation stations and bench marks in such a way that they can be picked up and utilized by other engineers at any future time. In connection with the works under my own charge, it has frequently been found that valuable records could not be utilized because bench marks and triangulation stations could not be found. Dr. Dawson in carrying out work for the determination of mean sea level, in connection with the Tidal Survey, has been unable to find any bench marks on the Intercolonial Railway, although the work was done by the Government of Canada. Mr. Stewart, in his re-survey of the lakes, has frequently been unable to relocate the main triangulation stations established by the United States Lakes Survey.

Two years ago this Society took steps, on my initiative, to draw the attention of the Government to the necessity for the

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permanent marking of bench marks and main triangulation stations. The records of such marks should be kept in that central bureau, of which the establishment has just been advocated. It is probable that the Geographer of the Government, who is to favour us with a paper, during this meeting, will have something to say on the subject of the laxity prevalent in recording levels, which gave him much trouble during the compilation of his list of Altitudes in Canada.

It has been the practice of Presidents of such societies as this, in their annual addresses, to make some reference to the work with which they have been more immediately connected. A passing mention of the engineering work under the charge of the Dominion Department of Marine and Fisheries may therefore be allowed. This Government Department, first organized after Confederation, was placed in charge of all aids to navigation, which had previously been administered by the several Colonial Governments, and by a few semi-independent boards, in rather a casual way.

In Canada as it existed at Confederation, with an immense coast line on the Atlantic and on her inland waters, and with an extremely small revenue, the problem of increasing aids to navigation was at first an exceedingly difficult one. The physical characteristics of the country, making her dependent upon the great lakes and the St. Lawrence River for internal communication, and on her ocean shipping for trade with Europe, was such as to emphasize the importance of all possible aids to navigation.

The department was fortunate in securing as its first Minister a man of the energy of the Hon. Peter Mitchell, and as its first engineer a man of the constructive and executive ability of Mr. Joseph Tomlinson. By adopting cheap wooden lighthouses and placing in them illuminating apparatus not too complicated to be operated by the uninstructed lightkeepers employed, it was possible rapidly to surround our coasts with a cordon of lighthouses, not of first-rate quality possibly, but sufficiently effective to give valuable aid to our growing commerce. Until the last decade this policy of rigourous economy was enforced, but since then the revenues of the country has increased in a remarkable manner, and the means available for the construction and maintenance of improved navigational facilities have kept pace with the increase in total revenues, so that at present it is possible to employ a much more liberal policy towards this important branch of the public service, especially in the inauguration of more powerful lights and fog alarms, and in the improvement of existing stations as necessity requires. The subsequent enlargement of the Dominion by the inclusion of British Columbia opened up a new field for work on the Pacific Coast, which the completion of the C. P. R. and the discovery of gold in the Klondike brought rapidily into prominence. My department

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has met the requirements on that coast by a liberal establishment of lights and fog alarms, buoys and beacons, placed with a promptness that has elicited praise not only from our own sailors, but also from United States captains using the intricate, but beautiful and sheltered channels between the islands and the mainland of that picturesque province.

At the time of confederation there were throughout Canada 227 lighthouses at 198 stations, and only two of these were equipped with steam fog whistles. Since 1867 there have been established in the Dominion, 769 new lighthouses at 598 different stations, 71 power fog alarms, 15 fog bells, 10 explosive fog signals, 89 signal buoys, and 106 gas lighted buoys, numbers far exceeding the total establishment of any country in the world except the United States of America, and very little inferior to the aggregate in that country of great wealth and magnificent distances. A majority of these appliances were designed and put in operation under the superintendence of myself, who for a long time, happily now past, enjoyed the distinction of being the only lighthouse engineer in Canada. Of late years our attention has been turned to improving aids rather than to rapidly increasing their numbers. In lighthouse illumination catadioptric lenses are rapidly being substituted for the older fashioned, simpler, and less expensive paraboloidal reflectors, and petroleum vapour burnt under incandescent mantles is taking the place of the ordinary oil light. These petroleum vapour lights are very efficient and economical. Photometric tests show that ten times as much light can be got from the vapour burnt under mantles as from the same oil burnt through wicks. The possibility of increasing the power of our Canadian lights is unfortunately limited by the capacity of our lightkeepers. As long as these officials are put in charge of stations without any previous instruction in their duties, so long will it be necessary to limit the size of the lamps to such as can be managed by ordinarily intelligent men. To place lamps with large, intensely hot flames in the hands of uninstructed keepers is to invite destruction of the buildings and apparatus. Until the appointment of lightkeepers can be restricted to young men nominated to go through a course of preliminary training under competent instructors, with the power of instant dismissal for breaches of duty in the hands of the Inspectors, it will be impossible to much further improve our lighthouse installations.

Most of our gas buoys and some of our small fixed lights are now using acetylene in compressed form as an illuminant, but there are difficulties, not the least of these being its cost, which will militate against its general adoption, especially in the face of a rival so formidable as petroleum vapour.

Electricity has never been used to any great extent in our lighthouses for many reasons, one being the liability of the machinery

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to break down, another the untrained lightkeepers we are obliged to employ. In the vicinity of towns having municipal or private electric plants, electric lights have in a few instances been installed, operated by the municipal power station. An important advantage of electricity, where it is available, is the facility with which occultations can be produced.

With the increase in the size and draught of modern steamships has come the necessity for widened and deepened channels, as well as for the better demarcation of those channels. In the River St. Lawrence, between Montreal and the sea, the 30-foot ship channel is now marked, not only by splendid range lights in the axes of all the deepened cuts, but also by gas buoys replacing the old unlighted buoys at all salient points, so that it should be possible to bring a large ship up to Montreal by night almost as readily as by day. The wonderfully ingenious Pintsch gas buoy, with its equally ingenious automatic occulting attachment, has done more to safeguard in narrow channels night navigation than any previous invention, and Canada now has these buoys established at all critical points between the Saguenay River and the head of lake navigation, marking the 14-foot channel in the canalized stretches of the St. Lawrence, as well as the sea-going ship channel.

In exposed positions on the sea coasts whistling buoys on the Courtenay principle, another clever invention, and the old-fashioned bell buoys, are used more extensively than gas buoys, being better adapted to stand the shock of the waves, and requiring no special attention beyond periodical lifting to remove sea growths and renew the moorings. The work of placing and renewing the 89 signal buoys now in commission, and the thousands of smaller buoys, studding all our harbours and rivers, employs quite a fleet of steam tenders.

A modern lightship, such as those lately moored off Anticosti and off Lurcher shoal, in the Bay of Funday, is a perfect battery of ingenious mechanisms. From the electric lights at her mast heads, automatically occulted by clockwork making and breaking the current produced by a dynamo in the engine room, to her moorings, connected with powerful automatic buffers and steam windlasses to relieve the strain on her bows, she is full of interesting machinery. She is self-propelling, provided with a powerful fog alarm, a submarine bell, and a Marconi telegraph instrument. For the design of these latest vessels we are indebted to the United States Lighthouse board, whose plans were adopted under the conviction that their long experience with lightships in the open Atlantic was too valuable to be ignored.

The first Canadian fog alarms were steam whistles. About 1873

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reed horns were substituted, from motives of economy, a very simple and fairly effective arrangement, patented in Canada, being adopted. In these machines the lifting of a piston in a steam cylinder compressed air in a larger cylinder immediately above, and forced it through the horn, so that the length of blast was regulated by the stroke of the steam piston. One of these horns has been heard 26 miles under favourable conditions. They were not, however, considered first rate fog alarms, and when larger grants became available, syrens of the Scotch and English types were adopted as the most powerful sound producers obtainable. A first-class English syren at Belleisle is operated by air compressed half a mile from the syren house, the power being obtained from a Pelton wheel run by water led from the lakes on the hills of the island. This installation has run successfully for many years, the cost of maintenance being a mere trifle.

The Government is now substituting diaphones for all the types of instruments previously used for fog alarms. These instruments are claimed to give a very penetrating sound. They have the advantage over the syren that they can be kept at a constant pitch, and if the Canadian patentees succeed in producing perfect resonation they will doubtless prove superior in sound carrying capacity to any signal yet invented. They are run by compressed air, and we are installing oil engines to operate them, because it is frequently difficult to obtain sufficient fresh water for steam engines at our fog alarm stations. The sound is produced by the free vibration in a slotted cylinder of a very light slotted piston, the air being admitted in rear of the piston, and escaping through the slots, which are alternately opened and closed sufficiently fast to produce a pure musical note.

A survey of the tides and currents of the Dominion is being conducted under the charge of Dr. W. Bell Dawson, one of our members. This survey, although having marine information for its more immediate object, yet requires to be based on engineering methods for its successful accomplishment. Its problems include construction and mechanical appliances, and questions in astronomy, physics and hydraulics require consideration to make the work effective.

Tide tables, based upon very complete gauge records, are now issued for the whole Dominion. The velocity and direction of currents have been determined in the St. Lawrence as well as upon the most dangerous parts of the Atlantic coast, and the results placed in the hands of mariners.

The tidal results have already proved valuable in connection with harbour construction, docks and dredging. Mean sea level, which the modern method of reducing tidal observations determines

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so accurately, affords the only trustworthy plane of reference for geodetic surveys. The Tidal Survey, by maintaining a uniform datum for the observations from year to year, has already referred mean sea level to bench marks established at Quebec, Halifax, and St. John, N.B. There are now also Bench Marks and sufficient tidal record for this purpose at a number of widely separated points in the area extending from the St. Lawrence to Newfoundland, and from Labrador to Nova Scotia. These isolated bench marks ought to be connected by continuous levels. Some admirable work has already been accomplished in this direction by Mr. R. Steckel, of our Society, and it is unfortunate that the pressure of more urgent duties has prevented the prosecution to completion of this scientifically important connecting link. The same data are also being determined on the Pacific coast at Victoria, Vancouver, and Port Simpson.

For hydrographic charts, Canada was for a long time dependent upon the surveys made in the early part of the last century by that well-known hydrographer, the late Admiral Bayfield. The immense quantity of work accomplished by that distinguished naval officer, and the wonderful accuracy of his charts, considering the rapidity with which he must have worked, and the clumsy vessels at his disposal in those early days, are beyond praise, but naturally these early charts became more or less unreliable with the introduction of deeper draught vessels and steam navigation. In 1887 this Department borrowed from the Admiralty the services of a hydrographic surveyor, Staff-Commander Boulton, who organized a re-survey of the great lakes, which has since been continuously carried on. We now have modern charts of the Canadian shores of all the great lakes except Ontario, and portions of Lake Superior unfinished. On Captain Boulton's retirement he was succeeded by Mr. W. J. Stewart, his pupil, and a graduate of the Royal Military College, and also one of our members, who has lately been put in charge of all our hydrographic surveying. Last year this Department took over from the Department of Railways and Canals a hydrographic survey of Lake St. Louis, and also took over from the Public Works Department the staff, engaged on the re-survey, nearly completed, of the ship channel between Montreal and Quebec.

There is still much work in this branch ready for attention when such can be given to it. The Maritime Province shore of the Gulf of St. Lawrence requires re-surveying, and a great deal of detail work is also required on our Pacific coast. If the advocated railway to Hudson Bay for the shipment of northwest grain by that route ever becomes an accomplished fact, the Marine Department will be called on for extensive work both in surveying and

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establishing aids to navigation in that remote Canadian sea, for existing charts of its coast lines are merely the roughest kind of sketches.

Several small hydrographic surveys have been made by the department, the most extensive of these being a survey of the whole of Lake Winnipeg, which has occupied Mr. Stewart or one of his assistants for the past three years.

We have not yet undertaken the publication of charts, these being engraved and published by the Imperial Admiralty without cost to us, but there is a staff for the collecting, editing and publication of descriptions of aids to navigation, sailing directions, hydrographical notes and other information of value to mariners, that is doing very creditable work.

The experience of this department with ice-breaking steamers is worthy of a word of reference, but most of the facts were brought out in papers and discussions before this Society some years ago, and need not be enlarged upon here. We have had charge, since the inception of the enterprise, of the winter ferry between Prince Edward Island and the mainland. The first steamer used of the service was built from the plans of Mr. Edmund Sewell, of Quebec, and embodied the results of his experience in the winter ferry service at that place. The "Northern Light" was a wooden steamer and performed the service with a fair degree of success. It was replaced by a Scotch built steel boat, the "Stanley," which was, I believe, the first boat built of steel used as an ice-breaker. The "Stanley" in turn has been replaced by a larger, more strongly protected and more powerful steamer, the "Minto," which has done the best work of the three, but all have at times been caught in the heavy fields for periods varying from a few days to a few weeks.

The great quantity of grain now grown in our northwest has made shippers anxious to extend inland navigation to as late a date in the autumn as it may be possible to force a passage through the making ice, and the department has been strongly urged to assist the movement by extending the limit of time for removing buoys and all other floating aids to navigation, and by breaking ice where necessary. This autumn the lights in Lake Superior were kept open a fortnight later than usual, necessitating special arrangements for the removal of the isolated keepers; and Forth William and Port Arthur harbours were kept open by employing ice-breaking tugs. This allowed shippers to get out by the cheap water route a considerable portion of this autumn's crop.

Two ice-breaking steamers, built in Scotland for the department, have been put in commission this winter, the one to maintain a ferry between Pointe aux Orignaux and Murray Bay, the other to keep the river open, if possible, between Quebec and Montreal. This last proposition is rather in the nature of an experiment, as no one

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is quite sure how much can be accomplished or what the effect would be of preventing the ice bridge from forming.

The maintenance and improvement of the ship channel between Quebec and Montreal, begun by the Montreal Harbour Commissioners, and later assumed by the Department of Public Works, was last year transferred to the Marine Department, for the sake of consolidating control of the work. This channel is now 30 feet deep at low water, except over St. Augustine bar, where the least depth is 23 feet, but where there is a rise of tide of 16 feet. The immediate aim of the department is to complete the depth to 30 feet throughout, to make the least width 500 feet, and to light the whole extent for night navigation. The only serious work remaining to accomplish this is the widening from 300 to 500 feet of Cap à la Roche cut, an excavation in limestone. Judging by past experience, this work will no sooner be accomplished than a further widening and deepening will be asked for, to accommodate the ever enlarging steamers seeking the St. Lawrence trade.

The improvements in the Harbour of Montreal, with which you are all familiar, are being made under the control of the Montreal Harbour Commissioners, but with Government aid, supervision and approval. The city, the commissioners, and above all the Commissioners' engineer, our old friend and Past President, are to be congratulated on the fine concrete wharves, fireproof elevator, and permanent freight accommodation already built, or under contract, which will greatly increase the importance as a seaport, of Canada's metropolis.

The services enumerated, by no means cover all the technical work under the control of the Marine Department, but they serve to indicate the extent and diversity of engineering required in a new country, while the general prosperity in every part promises a bright future for our profession throughout this great Dominion.

After the reading of the address, Mr. C. H. Keefer, Vice-President, took the chair.

On motion by Mr. John Kennedy, seconded by Mr. E. Marceau, a very hearty vote of thanks was accorded the President for his most interesting address. In responding thereto, Colonel Anderson took exception to a remark made by Mr. Kennedy, that Government work was always well done. He explained that it was very often not well done because of the small amount of money that was granted. The engineers did the best they could with the money at their disposal, but the work was not as well executed as it would be if the grant were larger, which would be the case if the country were richer. Continuing, the President said that it was nothing new for him to admire Canada, or to be impressed with the future greatness of it, because he had been travel-

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ling about the Dominion from one end of it to the other for thirty years and knew its size and natural resources. It was not, however, until he had been thrown in contact with the very eminent men who had visited the Society last summer that he began to think that engineering work in Canada had not been so badly done. He thanked the audience for their attention during the reading of his address, which he thought must have been tedious in many ways to those who had nothing to do with the problems before the Marine Department, a work which he had nevertheless found very interesting.

Dr. Bovey remarked in regard to one of the ideas that the President had brought forward, viz., the suggestion of a bureau for the preservation of plans, that he thought it would be well if the Society at its meeting on Thursday took some action recommending that this suggestion be adopted by the Government. Dr. Bovey said that he thought it a great advantage that a member of the Society had been so fortunate as to receive the highest honour in the gift of the French Government for tidal work. He was sure that the President was proud of having on his staff a man like Dr. Dawson, who had won this honour from the French Government for the work he had done. He thought it an honour for the Society to number among its members a man like Dr. Dawson.

The President observed in regard to Dr. Bovey's first suggestion that it would be a good idea to bring it up at the business meeting on Thursday. In the meantime the matter might be discussed among the members.

Dr. Bovey said that he thought the matter hardly required discussion; that if it were taken charge of by a Committee composed, perhaps, of the President and Secretary, to draw up a suitable recommendation to the Government, he was sure the Society would endorse anything they might suggest. He thought that a suitable recommendation might be ready to lay before the meeting on Thursday for transmission to the Government.

The meeting then adjourned.

Wednesday, 25th January.

On Wednesday morning about 150 members assembled at Bonaventure Station, and were conveyed by special train courteously supplied by the Grand Trunk Railway, to the works of the Dominion Bridge Company at Lachine, where they were received by Mr. Phelps Johnson, Manager of the Company. The party also visited the works of the Dominion Wire Manufacturing Company, the Dominion Wire Rope Company, and the Allis-Chalmers-Bullock

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Company, and were hospitably entertained at luncheon by the Dominion Bridge Company.

In the evening the Annual Dinner was given in the Windsor Hotel, at which over eighty members were present. The chair was occupied by Colonel Anderson. The special guests present were: Mr. Wade, Chairman of the Transcontinental Railway Commission, and Dr. Haanel, Superintendent of Mines, Ottawa. Mr. Wade, in answering to the toast to "Our Guests," discussed the great work which was taking place at the present time in building the Trans-Continental Railway, which, if possible, the Commission had determined to accomplish with the aid of Canadian Engineers only. Whether this would be realized or not remained to be seen, but the idea was to exhaust the home supply before seeking for others abroad. In this connection, he did not believe there had ever been a time when there was so great a necessity for the work of the Society as at present, for upon it rested the duty of supplying the demand for engineers of the highest grade and class. He considered that the Canadian engineers were better adapted to the conditions and circumstances in hand than engineers imported from abroad, for the simple reason that the latter had to learn the conditions which were already known to the engineeers of this country. He therefore wished to assure the Society that in the work it had undertaken it would receive the unbounded support of the Commission he represented. The object of the Society was not to create a close corporation, but to make the profession more efficient, and in doing so, it would accomplish a great deal.

Thursday Morning, January 26th.

The meeting was called to order at 10.30 a.m. Colonel W. P. Anderson in the chair. The scrutineers for the election of officers and members for the year 1905 presented their report as follows:—

President:—Mr. Ernest Marceau.

Vice-Presidents:—C. H. Keefer, D. Macpherson and G. A. Mountain.

Councillors:—John Kennedy, W. F. Tye, G. A. Keefer, C. H. Rust, A. E. Doucet, Phelps Johnson, R. W. Leonard, P. W. St. George, W. B. MacKenzie, R. B. Owens, M. J. Butler, R. J. Durley, G. J. Desbarats, J. B. Porter, H. C. Burchell.

The scrutineers of the ballot for the election of the Nominating Committe reported the following elected:—

For Ontario:—G. A. Mountain, C. H. Rust and J. Galbraith.

For Quebec:—F. Shearwood and W. McLea Walbank.

For North-West Territories:—G. H. Webster.

For Maritime Provinces:—F. W. W. Doane.

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The following received one vote each as representative for outside Canada and Newfoundland:—Messrs. H. Irwin, J. G. G. Kerry, C. H. McLeod, J. Kennedy, and I. G. Hedrick. Mr. McLeod asked to withdraw his name, and a vote being taken, in accordance with By-law 40, Mr. H. Irwin was declared elected.

The Scrutineers of the ballot for the Amendment of By-laws reported the following amendments as submitted to have been carried:—

To amend By-law 4 by omitting the word "any" in the eighth line, and the whole of the last line.

To amend By-law 27 by omitting the words "a Librarian" in the second line, and changing the words "fifteen" in the fourth and fifth lines to read "twenty."

To amend By-law 31 by changing the third and part of the fourth line to read "by the Council, or by the Finance, or Library and House Committee."

To omit By-law 32.

To amend By-law 33 so as to be numbered 32.

To amend By-law 34 to be numbered 33, and to read: "The Council shall meet within one week after its election, and shall appoint, firstly, a standing committee of five on Finance, which shall have supervision of the accounts of the Society; secondly, an Auditor, who shall audit the books of the Treasurer and shall certify to his Annual Report; and, thirdly, a Library and House Committee of five, which shall have supervision of the rooms and library, and shall expend for the purchase of books or other articles of permanent value to the Society such sums as may be granted for that purpose. The Council shall also appoint a Secretary, a Treasurer and such subordinate officers as may be necessary for the proper conduct of the business of the Society at such salaries as it may deem fit. All officers having the funds of the Society in hand shall be required to give adequate bonds. The Secretary and Treasurer shall have seats and votes on the Council."

To add a new By-law to be numbered 34 to read:—"Three members of a standing Committee shall constitute a quorom thereof. Any member of a standing Committee who shall have failed to attend all regularly called meetings of the Committee during two months may be replaced by a vote of the Council."

To amend By-law 35 by omitting from the fifth line the words "Treasurer, Secretary, Librarian," by substituting the number "31" for "34" in the ninth line, by omitting the words "one for Treasurer, one for Secretary, one for Librarian," in the tenth and eleventh lines, by changing the words "eight" to "ten" in the 14th and 15th lines.

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To amend By-law 44 (A) by changing the words on the fifth line, "verified by the Committee on Finance" to read "certified by the Auditor."

To amend By-law 44 (C) to read "Ordinary meetings of the Society or of one of the Sections thereof shall be held on such Thursdays as may be arranged by the Council at eight o'clock in the evening during the months of October, November, December, January, February, March and April; but it shall be in the power of an ordinary meeting to make such special changes in these dates as may be deemed advisable."

Mr. Marceau, the newly-elected President, took the chair amidst applause. The retiring President spoke highly of Mr. Marceau's record, and referred to his zeal for the advancement of the Society.

Mr. Marceau disclaimed any special fitness for the position, but said that he would be stimulated by the examples which had been set him by his predecessors.

Mr. E. M. Archibald then read his paper on "The Effect of Load Factor on the cost of Electric Power."

On motion by Dr. R. B. Owens, seconded by Mr. John Kennedy, the thanks of the meeting were accorded to Mr. Archibald for his very interesting paper.

Thursday Afternoon, 26th January, 1905.

The meeting re-assembled at 3.00 p.m., Mr. C. H. Keefer, Vice-President, took the chair, owing to the unavoidable absence of the President.

The Report of Council came up again for discussion.

Dr. Porter speaking for the Library Committee referred to the report of that Committee as printed on pages 12 and 13 of the Annual Report of Council. He then explained in some detail the method that was being employed in selecting additions to the library, and also described the system of indexing and arranging the collections of trade catalogues.

Referring to the proposal to aid branch Societies in getting together libraries, Dr. Porter spoke of the considerable cost of even very small collections of books, and ventured to advise the Society to put the home library in reasonably good shape before it spent any considerable sums on the purchase of duplicate books for branches. The Society as a whole would, in his opinion, get more good from one fairly large library than from several very small ones, especially if the out of town members would take advantage of the arrangements already made to have subjects looked up, and abstracts made where necessary.

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Dr. Porter promised the early completion of the trade catalogue collection, and expressed the hope that this and the proposed new catalogue of the library, would prove of great value.

Mr. C. B. Smith urged that what was chiefly needed at local centres was an index to engineering literature and standard references; that it was also exceedingly important that provision should be made with a view to rendering the central library available by some circulating method.

Discussion on improving the usefulness of the Library was also taken part in by Messrs. Walbank, Rogers and Irwin.

On motion by Mr. G. A. Mountain, seconded by Mr. C. H. Rust, the Report of Council for 1904 was unanimously adopted.

On motion by Colonel Anderson, seconded by Mr. C. H. Rust, it was resolved that the Council be again requested to ask the members of the Society to see that their lines of levels are in all cases connected with permanent bench marks, and that these, where possible are connected with sea level datum. Further that the Council take into consideration the best method of securing permanent records in regard not only to levels, but also to all trigonometrical surveys, and to confer with the Government with a view to having it instruct its officers engaged in surveying to adopt such methods in regard to bench marks as would render them permanent both as to elevation and marking.

In discussion, Mr. Lordly remarked that Government officers experienced difficulty in getting permission to establish permanent benches.

Mr. John Kennedy said that this was a matter in which all engineers could assist by taking pains to mark their benches as permanently as possible.

Mr. C. B. Smith called attention to the imperfect knowledge in regard to a sea level datum, and stated that at Niagara Falls there were two data in use having a difference of nine-tenths of a foot.

Col. Anderson considered that the matter of prime importance was that engineers should refer to some datum and should describe that in such manner as might be understood by all.

Mr. G. J. Desbarats stated that the bench marks established along the St. Lawrence River by Mr. Steckel were very accurately connected, although their connection with sea level was not thoroughly known.

Mr. C. B. Smith then read his paper upon "The Construction of the Canadian Niagara Power Company's 100,000 h.p. Hydro-Electric Plant at Niagara Falls, Ont."

Mr. Smith's paper was illustrated by some very interesting

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lantern slides. At the conclusion the author was accorded the thanks of the meeting for his valuable contribution.

The following votes of thanks were then passed:—To the various railways, on motion by Mr. R. B. Rogers, seconded by Mr. C. B. Smith; to the Dominion Bridge Company, on motion by Mr. L. G. Papineau, seconded by Mr. C. de B. Leprohon; to the Dominion Wire Manufacturing Co., the Dominion Wire Rope Co., and the Allis, Chalmers, Bullock Co., on motion by Mr. W. McLea Walbank, seconded by Mr. R. S. Lea; to the Grand Trunk Railway, on motion by Dr. J. B. Porter, seconded by Mr. J. F. Farmer; to the Press, on motion by Mr. G. H. Dawson, seconded by Mr. D. Macpherson; to the gentlemen who assisted in the musical programme of the dinner, on motion by Mr. G. H. Dawson, seconded by Mr. J. A. Jamieson; to the retiring officers, on motion by Mr J. A. Jamieson, seconded by Mr. R. S. Lea; to the Committee on arrangements for the Annual Meeting, on motion by Mr. C. H. Rust, seconded by Mr. W. F. Tye.

Thursday Evening, January 26th.

The meeting re-assembled at 8.00 p.m., Mr. E. Marceau, President, in the chair.

Mr. James White, Dominion Geographer, read a paper on "Maps and Map Making in Canada," and in connection therewith exhibited a valuable collection of maps illustrating the development of map-making. Mr. White's paper was illustrated by a large wall map showing the existing state of mapping in Canada.

A hearty vote of thanks was tendered Mr. White for his very valuable paper.

At the conclusion of Mr. White's paper, Dr. E. Haanel delivered a lecture descriptive of his investigations on "The Electro-Thermic Production of Iron and Steel."

At the conclusion of the address, Dr. A. Stansfield, of McGill University, exhibited a small Heroult furnace, which had been described by Dr. Haanel. This furnace was started cold and in less than twenty minutes it had produced a small quantity of steel.

Dr. Haanel's address was enthusiastically received, and the thanks of the meeting were tendered to the lecturer and Dr. Stansfield.

The meeting then adjourned.

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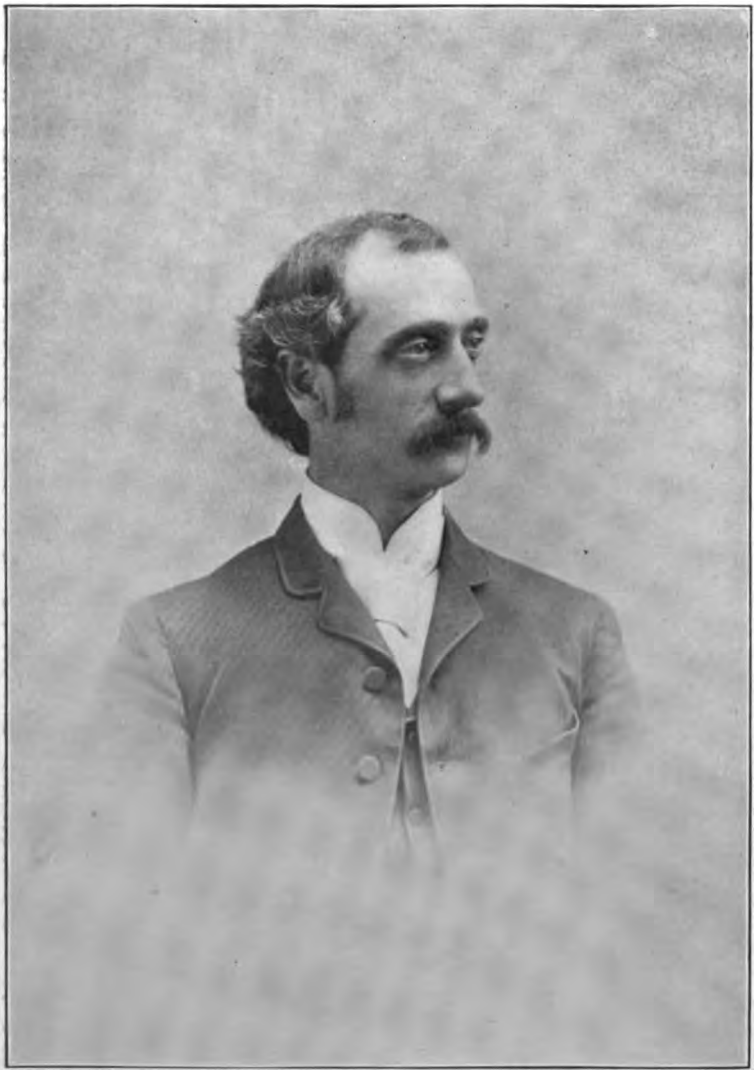

Ernest Marceau

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BUSINESS MEETING.

A business meeting of the Society was held on Thursday, January 12th, 1905, Mr. W. McLea Walbank in the chair. The annual auction sale of periodicals was conducted by Mr. J. M. Nelson.

MECHANICAL SECTION.

President—PHELPS JOHNSON.
Vice-President—M. J. BUTLER.

A meeting was held Thursday, January 19th, 1905, Mr. Phelps Johnson in the chair. The following paper was read:—

PAPER No. 218.

THE PROPORTIONS AND DESIGN OF LOCOMOTIVE CROSSHEADS.

By W. F. DRYSDALE, S. Can. Soc. C. E.

The locomotive crosshead is that block which connects the end of the piston rod with the small end of the connecting rod, and running between guides, prevents undue strain being transmitted to either connection. It must be so simple as to be easily handled and kept in repair, it must be strong enough to withstand a large amount of rough usage due to accident rather than piston thrust, and lastly it must be so designed that little work is absorbed by it in friction.

We shall endeavour to study its development from its earliest form to the standard types as now used on modern locomotives.

Although Trevithick's locomotive of 1803 had no crosshead, in it were embodied the three main features of one, namely, piston rod connection, main rod connection, and a common guide for both. Fig. 1 shows a plan and side elevation of this arrangement where "a" is the piston rod, "c, c" the connecting rods fastened to the beam "d" and guided by the bars "b, b."

Fig. 1. (A) shows a modification of the above, in which only one connecting rod was used.

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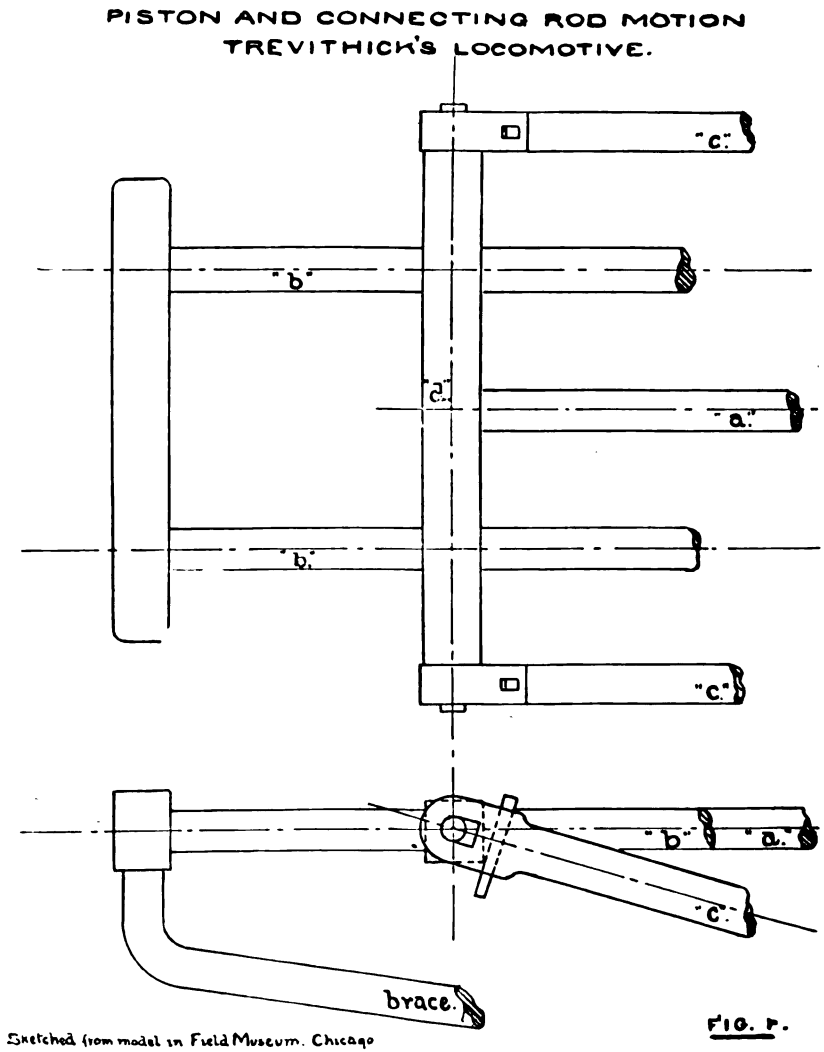
Stevenson's "Rocket," 1829, was the first locomotive to use a crosshead. This consisted of a small block running between two guides; a short connecting rod, which must have caused great ver-



tical thrusts on the guide bars, was a noticeable feature. In the early thirties American designers adopted a crosshead which was guided top and bottom by round bars. (fig. 2.) Lack of ready ad-

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justment to wear, and weakness were chief points in this design. Then came the two-bar crosshead as seen in fig. 3. The guide bars were made of boiler iron, a cast iron head being used.

Fig. 4, shows a crosshead used on the "James," built by Wm.

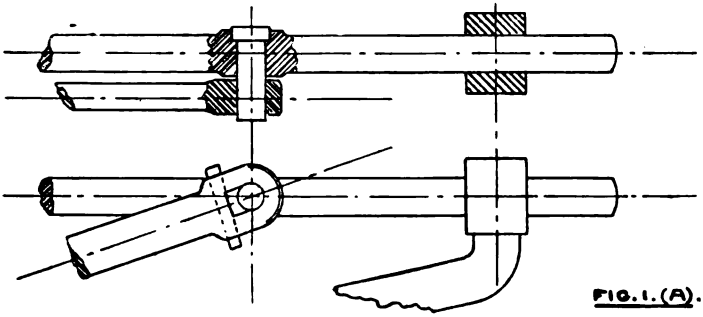


FIG. 1. (A).

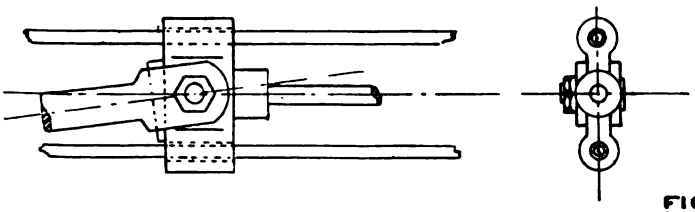
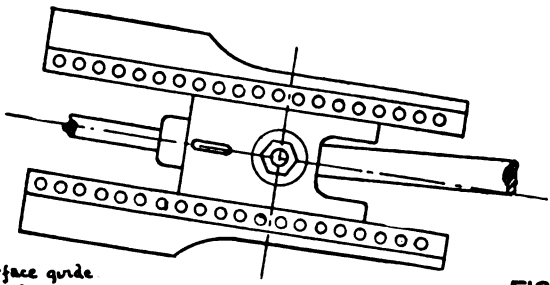


FIG. 2.



Two bar plane surface guide
Adopted on first mogul ever built.
Eastwick & Harrison. 1839.

FIG. 3.

T. James, of New York, for the Baltimore and Ohio Ry. in 1832.

Fig 5 as on the "Sandusky" built in 1837. Fig. 6 that on the "Pioneer," the first locomotive to run into Chicago. In the early fifties American designers adopted the single bar type. Commencing

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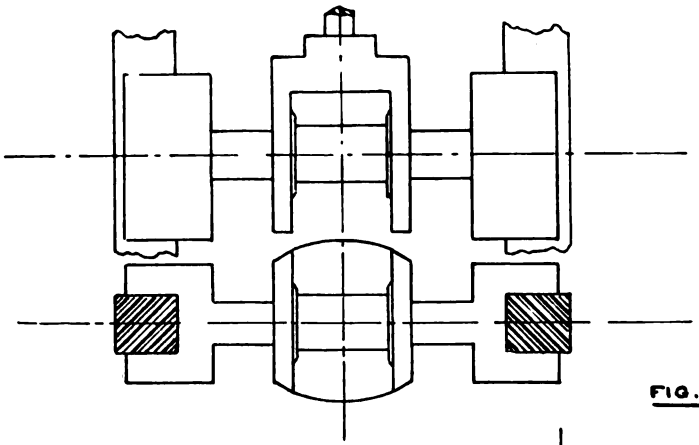


FIG. 4.

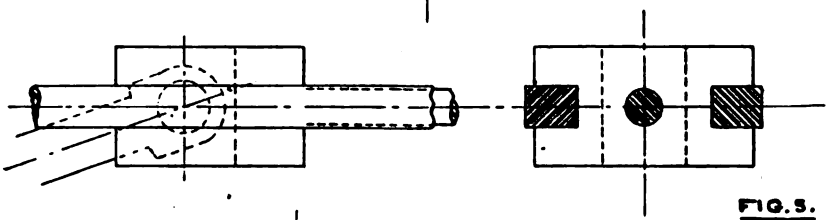
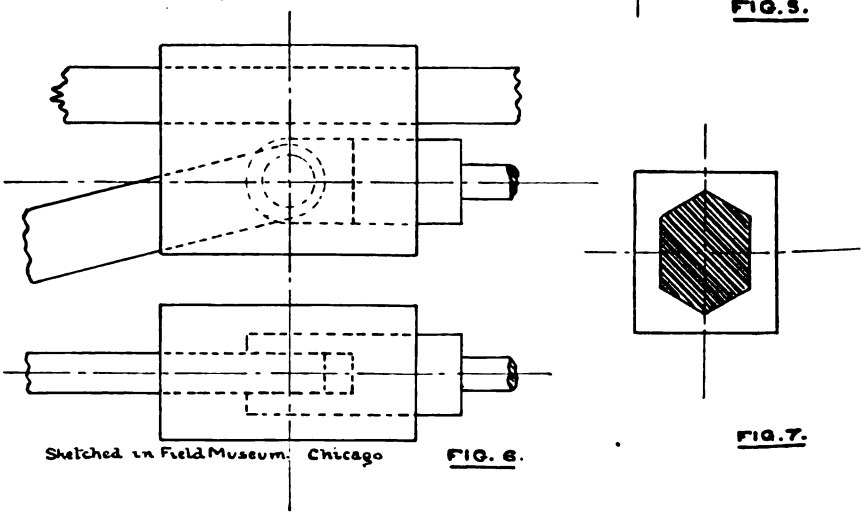


FIG. 5.



Sketched in Field Museum, Chicago

FIG. 6.

FIG. 7.

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with a bar of section shown in fig. 7, they finally adopted the simpler rectangular shape (fig. 15.). We may here note that the early designers made no attempt to transmit their power through a parallel motion, and we shall presently see that they were justified in sacrificing force for the sake of simplicity of construction.

MODERN FORMS.

Locomotive crossheads, the world over, belong to three classes: namely, the two-bar, the four-bar, and the single bar types. It is true that there are many heads that do not come under the above classification, but they are special designs and not standard. The two-bar type, as seen in figs 8, 9, 10, 11, is the most common head seen on the American Continent. The guide bars are equi-distant top and bottom from the piston rod and are central with the vertical plane of the cylinders. The pin is always separate, and lies under the centre of the slipper block. The heads are usually made in cast steel with brass shoes top and bottom, and steel pin, as seen in figure 8.

A cast iron type (fig. 9) is common in which the socket is reinforced by ribs cast between it and the shoe supports—see "a, a" in the figure.

It is usual on this type to use brass liners on the sliding surfaces, with a cast iron flange bolted on as shown at "b b." This head is not as simple as that seen in fig. 8, and is being supplanted by the latter on many of the large American Railway Systems. The four-bar type, seen in figs. 13, 14, and 16, consists of two blocks which run on either side of the piston and connecting rods, and are joined in one casting which forms connection for piston rod and also the pin around which the connecting rod end oscillates. The casting is made of good wheel cast iron or cast steel. Although the crosshead pins are usually part of the casting, on some roads separate pins are used. The weak features of this design are that the pin does not always lie under the centre of the slipper block, giving uneven distribution of pressure on it; when the pin is cast, it is always a difficult operation to machine it and keep it in order; also four sliding surfaces are more difficult to deal with than two. When made in cast iron this type is weak at points "a, a," "b, b" and "c, c." To prevent breaking some roads have ordered wrought iron bands to be shrunk around the flanges next to the inside of the bars.

The guide bars are made of wrought iron, case-hardened, and ground with emery wheel to the proper surface.

A crosshead which belongs to this class is seen in fig. 14, which represents the head used on the Vauclain compound made by Baldwins, of Philadelphia. In this the high and low pressure

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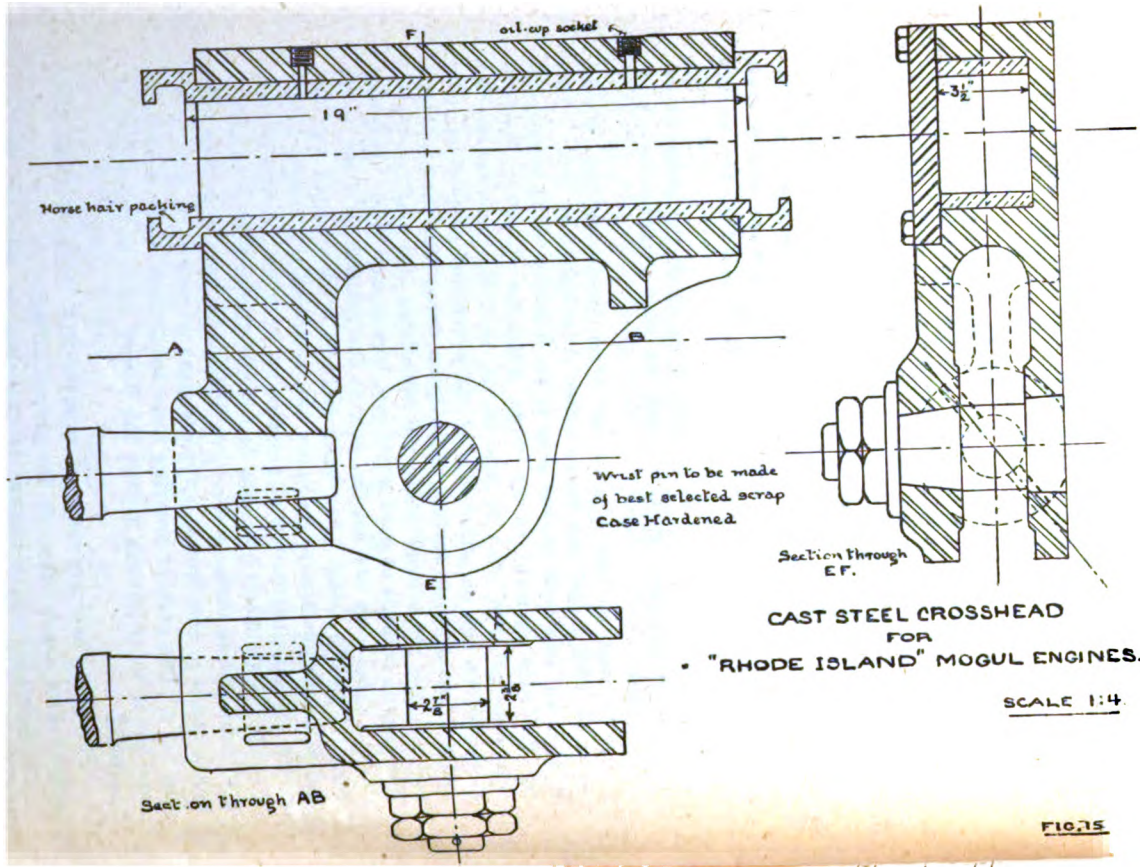

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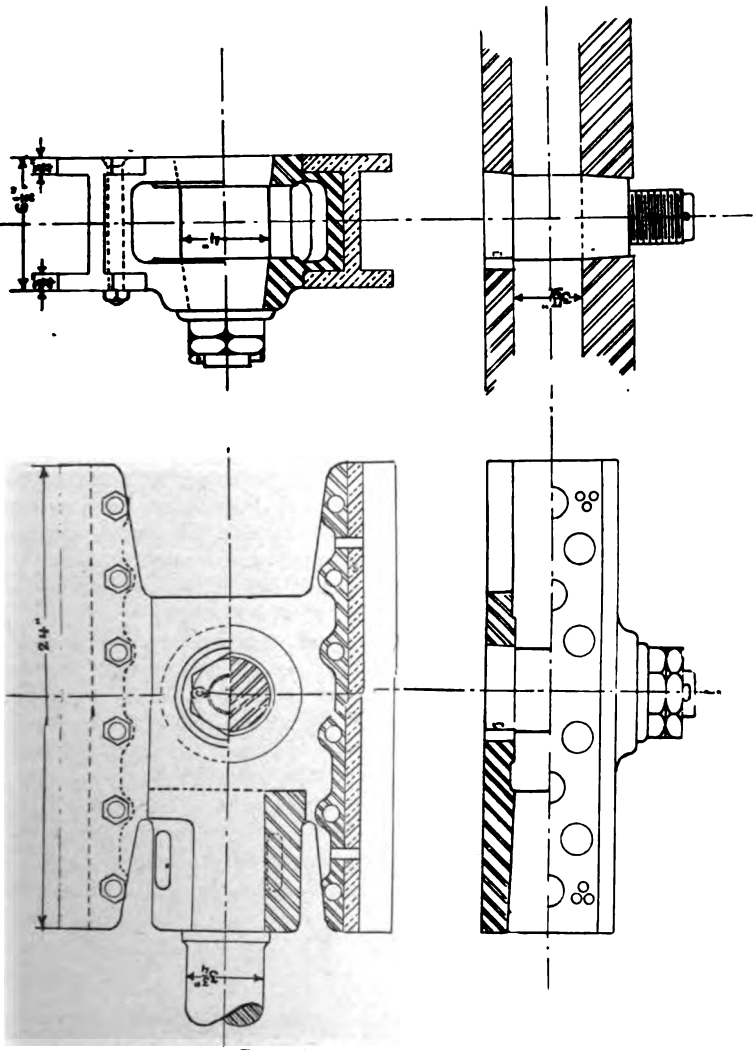
piston rods are connected on each side to a single head. The four sliding surfaces are situated horizontally outside and vertically between the piston rods. An open hearth steel casting with block tin,



CAST STEEL CROSSHEAD, G. T. RY. SYSTEM.
20 x 26 Engines and Rich. Comp.

1-16″ thick, lining, for all bearing surfaces, and a separate steel pin, are the principal features. It is a well designed crosshead and gives very little trouble on the road.

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The single-bar type:—Fig. 15 shows a crosshead which has been used successfully for many years on roads in the United States. In it the crosshead embraces a single guide bar, the lower rubbing surface being lubricated by means of oil holes drilled in the guide bar. It is a strong head and gives a large amount of clearance for the connecting rod, and other parts, besides it is simple in construction and easily lined up.

Fig. 18 represents a form of crosshead where both guide bars are placed above the centre line of the piston rod. A forked jaw carries the pin, whose centre is in direct line with cylinder and piston rod centres. "A" (see fig.) is a crosshead filling piece which is bolted between the two checks "b" and "c" of the crosshead. This is a simple crosshead to set up, all that is necessary being to clamp up both bars to embrace the filling piece, raise the crosshead up, and bolt it in position. This crosshead is used where the driving wheels come opposite the slide bars, as in mogul or consolidation engines. One weak feature of this design is that it is hard to adjust the sliding surfaces for wear. Fig. 11 shows a design used by Baldwins on their Vauclain compounds. It has evidently been designed to give clearance for a short connecting rod.

It may be interesting, at this point, to glance at some of the designs used on British locomotives. In Fig. 16 we have a form which is in common use on inside and outside connected engines. It belongs to the four-bar type; a wrought iron crosshead carries a pin which acts as journal for the forked end of the connecting rod "a, a" and the cast iron slide blocks "b, c."

Brass liners are sometimes inserted between the surfaces of blocks and guides to reduce friction. In all of its other features it is similar to the American four-bar type, as already described. Fig. 17 illustrates a head in which the piston rod and slide block are forged in one piece, and the whole is free to turn round a case-hardened wrought iron journal, which is keyed to the connecting rod, except for the constraint of the guide bars. This is an expensive design, is weak in support, and would withstand little side twist. Fig's 19 and 20 show by end views the chief feature of construction of three-bar types, which are in use to-day. The guide bars are shown in section.

Comparison of Parts.

Strength of Guide Bars.—All guide bars should be made strong enough to withstand excessive shocks such as they would be subjected to if a rod were knocking at its brasses badly, or any other of the extra destructive effects due to an engine jolting over a rough track

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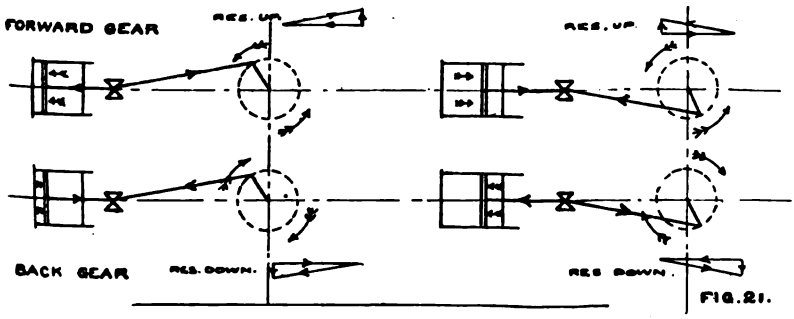
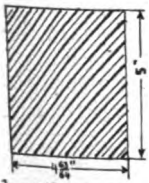


FIG. 21.

TABLE I.



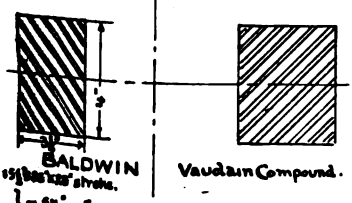
MORSE MOGUL
G.T.Ry. System.
20"x26"x63" DRIVERS.

$l = 34\frac{1}{2}$" $I = 52$ $f = 6000$#/□" $y = 2\frac{1}{2}$"
$M = 125000$ "# $m = 66500$ "#.

In considering max. bending moment on bar it having fixed ends, take $m = \frac{Wl}{8}$ where W = max. force acting at centre.

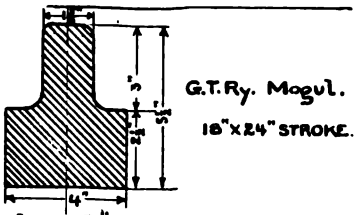
BALDWIN
14"x22" SWITCH. ENG.

length of slide bar (l)	$47\frac{5}{8}$"
moment of inertia (I)	11.41
safe stress per sq in. (f)	6000#
neutral axis to outside (y)	$1\frac{3}{16}$"
moment of resistance (M)	84200 in. lbs.
max. moment on bar (m)	17275 in. lbs.



BALDWIN
15"x26"x22" stroke.
$l = 64$" $I = 17.33$ for each bar
$f = 7000$#/□" $y = 2$"
$M = 60700 \times 2 = 121400$ "#
$m = 89500$ "#

Vauclain Compound.



G.T.Ry. Mogul.
18"x24" STROKE.

$l = 55\frac{3}{8}$" $I = 33.54$ $f = 5000$#/□"
$y = 2\frac{1}{4}$" $M = 44,720$ "#. $m = 44200$ "#.
Cast Iron bars break frequently, but give excellent satisfaction while running

STRENGTH OF GUIDE BARS.

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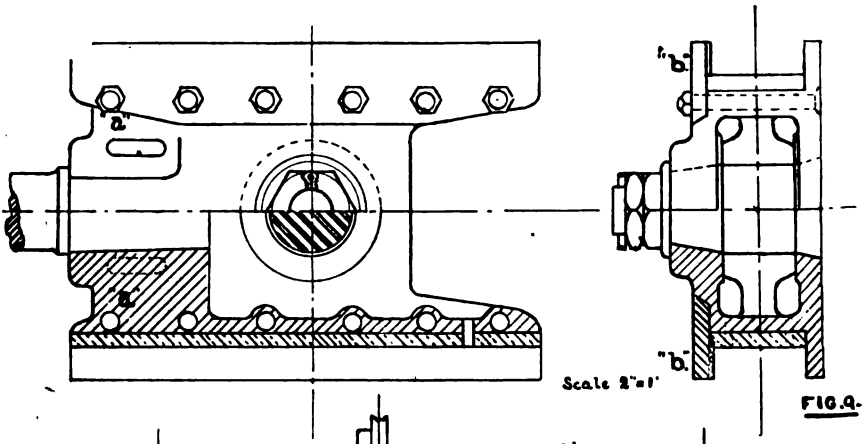


FIG. 9.

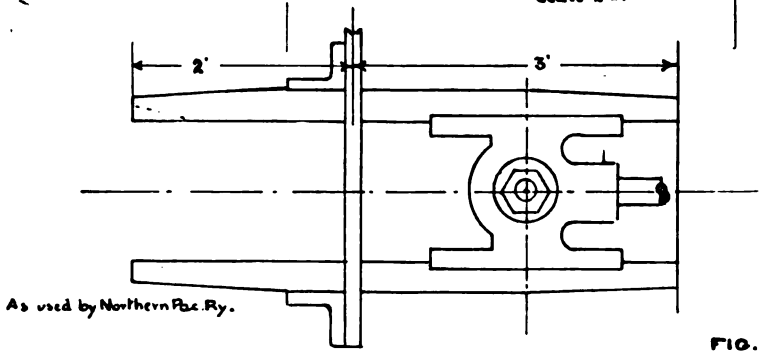
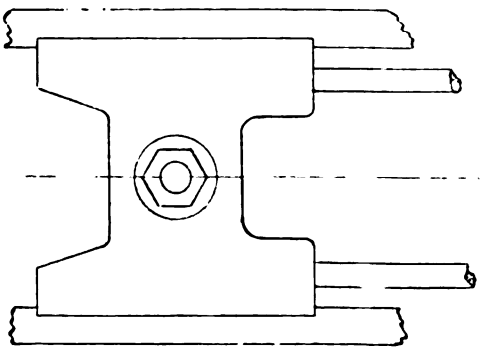


FIG. 10.



BALDWIN

VAUCLAIN TYPE

FIG 11

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The guides are always subjected to great vertical strains. To resist these they must be strongly bolted at the front end to the back cylinder head, and at the back end to the guide yoke (see fig. 18) which in turn is bolted to the engine frame, and usually also to the boiler.

The section of the guide-bar is always greatest opposite the centre of the crosshead stroke, as this is the place where the maximum upward thrust takes place, and, since most bars are supported to the ends, here the greatest bending moment is found. Guide bars are made of steel, cast iron, and wrought iron. It is the opinion of many railroad men that the cast iron bar gives the best satisfaction of all. The rubbed faces of these bars are often chilled in diagonal strips to make them wear better. All wrought iron bars are case-hardened and ground.

It is better that the surface of the slipper blocks should wear before the guide bars: to ensure this the slipper blocks are lined with a softer metal than the guides are made of.

The top bar must be made stronger than the bottom bar, for in locomotive work the engine is running in forward gear more often than it is running backwards—now while in forward gear all pressure comes on the top bar and vice versa—the reason that this is so may readily be seen by examining fig 21. By taking the connecting rod in two positions for each direction of motion, and resolving the forces and reactions which keep it in equilibrium, by the triangle of forces we can see that this statement is so. Of course we here suppose that the centre of the cylinder comes in direct line with the crank pin centre; if this is not so, the statement is not absolutely correct.

In fig. 10 we see a bar supported at a point two-fifths of its length from the end. This is a good feature, in that the bar receives the maximum thrusts close to its point of support.

The stress on the guide bars is due to the pressure of the steam on the piston, acting obliquely on the crank, and is greatest when the crank is at right angles to the connecting rod. We shall here only consider the maximum thrust, and for simplicity, we will imagine the steam pressure constant throughout the stroke; neglecting the weight of parts, inertia forces, and frictional loss in cylinder and gland. See fig. 24.

S. is max. when A. B. C. is a right angle. From similar triangles it may readily be seen that

$$\frac{R}{nH} = \frac{S}{} \quad \therefore \quad S = \frac{P}{n}$$

We shall by the above formula, knowing the values of P, n, and moment of inertia of the guide bar, etc., determine the relative resistances of four types of bar. See "Table I."

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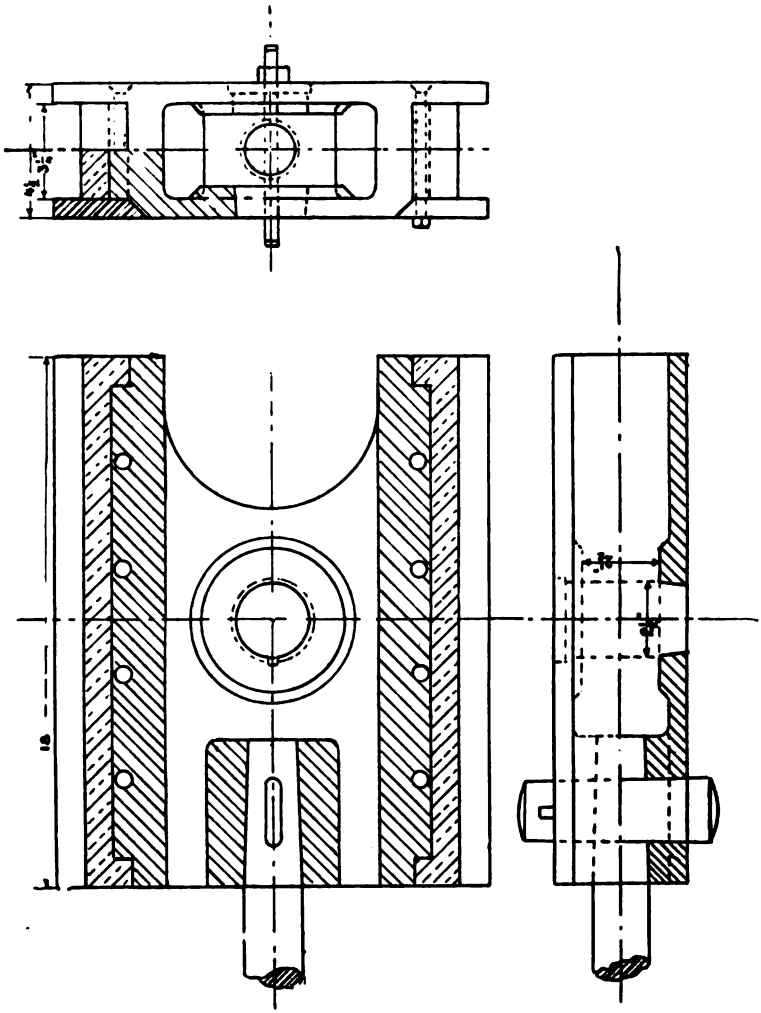
Clearance cuts, at the end of the guide bars (see "d d." fig. 18) are placed there to prevent the formation of a ridge at the point where the crosshead reverses, thus preventing, binding and

FIG 12.



CROSSHEAD, BALDWIN LOCO. 14 x 22 INCHES, SWITCHER.

throwing off any grease or dirt which the crosshead may have gathered.

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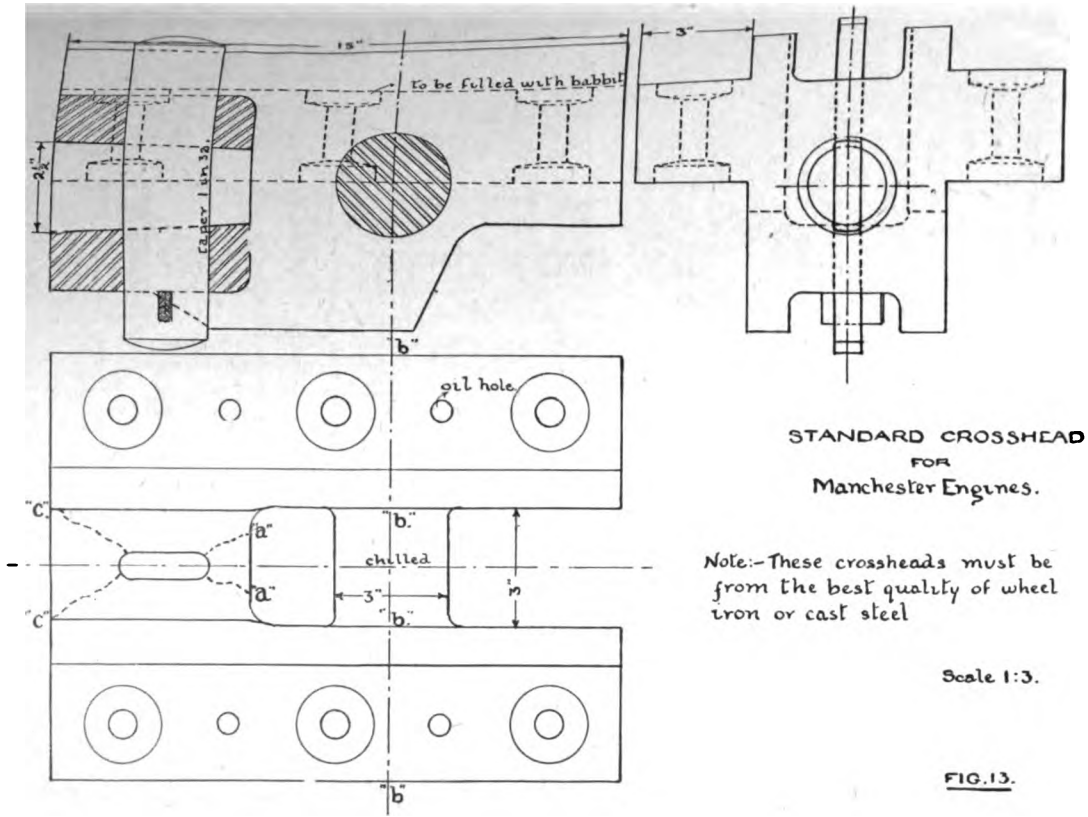

STANDARD CROSSHEAD
FOR
Manchester Engines.

Note:- These crossheads must be from the best quality of wheel iron or cast steel

Scale 1:3.

FIG. 13.

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FRICTION BETWEEN SLIPPER AND GUIDE.

Considering the fact that parallel motions are not used in locomotive construction, particularly in transmitting power from the cylinder to the driving wheel crank, we have to reckon with a considerable loss of power in friction, due to the resisting forces of con-

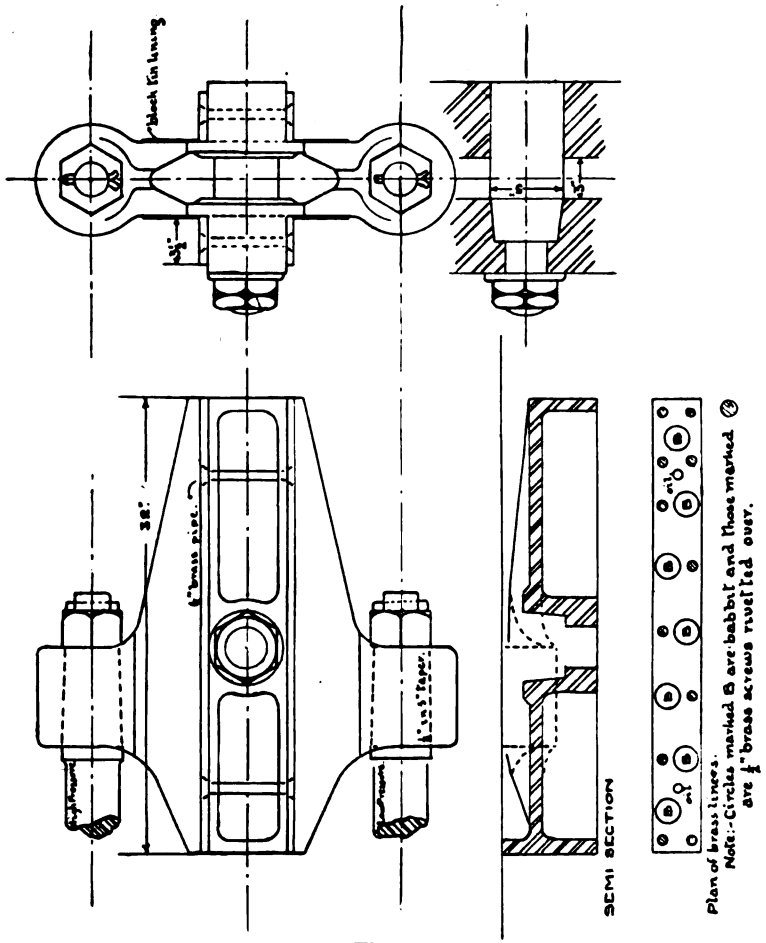

Fig. 14.

CROSSHEAD OF BALDWIN COMP. VAUCLAIN TYPE.

strained motion. It is the duty of the designer to so construct his parts that this loss may become a minimum. The frictional loss due to the weight of the reciprocating parts on the bars is neg-

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ligible as compared with that due to the upward and downward thrusts caused by the angularity of the connecting rod. To reduce friction we must therefore lengthen our connecting rod and thereby reduce its angularity. Again, the frictional loss may be reduced by having the rubbing surfaces made of, or lined with, some form of

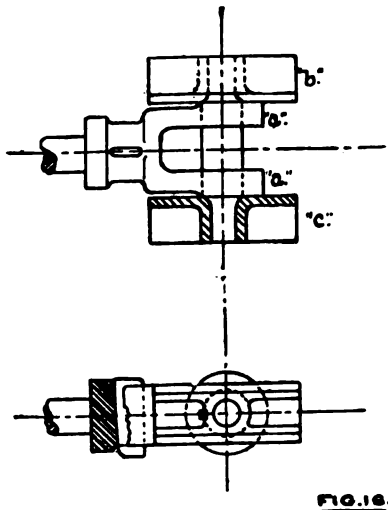

FIG.16.

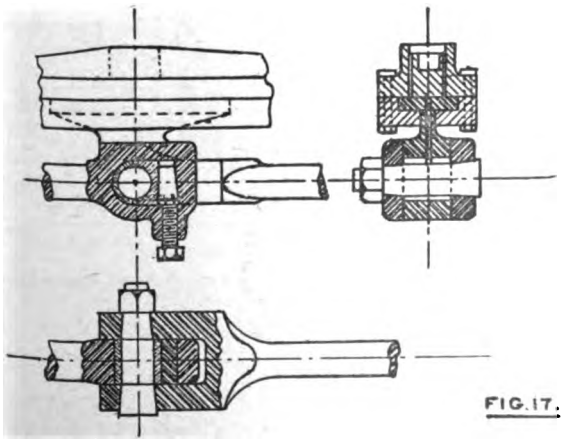

FIG.17.

anti-frictional material; also by taking care to have these surfaces at all times well lubricated.

Knowing the pressure on the sliding blocks, and their dimensions, we shall compare the intensities of pressure to which the

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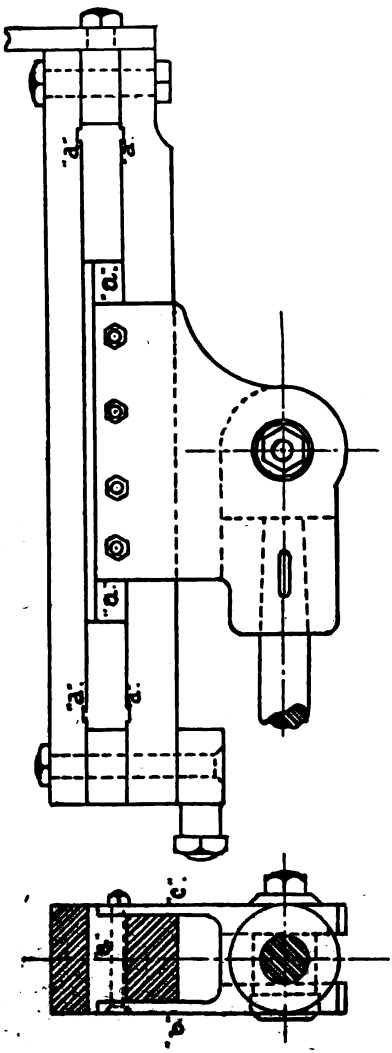
various materials used are subjected. In a preceding paragraph the means of determining the maximum thrust on the guide bars were explained. Taking this value and dividing it by the area of the



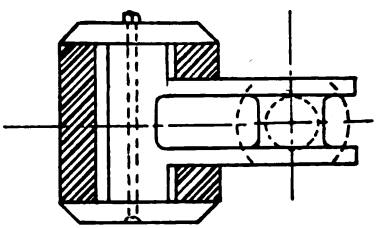


FIG. 20.

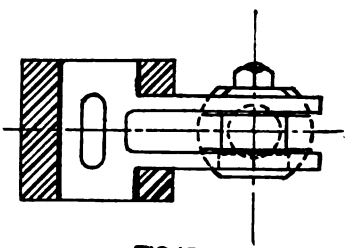


FIG. 19.

From sketches made in Roundhouse.

slipper block we arrive at the intensity of pressure. It is true that this intensity decreases at the ends of the stroke, and as the speed rises, but we are here dealing with the severest test it must under-

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go, which will take place on starting, when the value of the co-efficient of friction (u) is greatest. Knowing the amount of thrust on the guide bar, and the value of "u" for rest, we can readily compute the amount of force required to move the crosshead from rest.

Speaking of intensity of pressure on guide bars, an authority says:—"In locomotives having steel or case-hardened wrought iron bars the pressure is sometimes as high as 120 lbs. per sq. in. This is much too high, and will soon wear down the guides and crosshead gibs. The pressure per square inch should not exceed 40 lbs."

Compare the above with values seen in "Table II."

The pressure of oil or other lubricant between the rubbed surfaces tends to reduce the friction and lessen the heating.

The guide bar, slipper block, and crosshead casting must be of sufficient volume to allow the heat to dissipate freely, or else it will collect and result in "running hot."

In order to determine the starting effort, maintaining effort, and horse power wasted in friction, a value of "u" for crosshead and guide is necessary. All mechanical engineer's hand books contain values which are approximately true. Local conditions, such as the temperature of sliding surfaces, lubricant used, speed of rubbing, etc., have a great deal to do with these values.

In order to find the co-efficient for crosshead and guide as used on locomotives now being built by the Grand Trunk Railway in their Point St. Charles Works, the writer resorted to the following simple method:—A bottom guide bar was placed flat on the floor, a block and tackle was fastened to one end of the bar, while the crosshead was allowed to lie freely on the level surface of the bar. The block and tackle then gradually raised one end of the bar while the other end acted as a pivot. This operation was performed slowly, the bar being constantly rapped with a copper hammer to prevent sticking, until the angle of repose was reached and the crosshead started from rest. The angle ϕ was determined by means of a spirit level and protractor.

The following were the results:—

As experimentally determined.

Surfaces.	u.	Conditions.	Remarks.
Brass on Wrought Iron	.1405	dry.	Atmospheric temp.
do.	.1317	oiled.	about 82° Fah.

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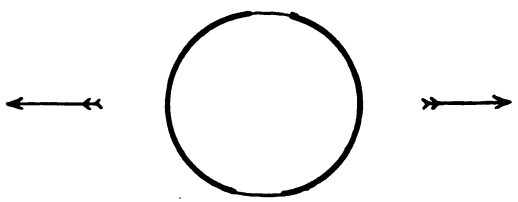
Jenkin and Ewing's results.

Surfaces.	u,	Conditions.
Cast Iron on Wrought Iron	.171	dry.
Steel on Brass.	.146	oiled.

DESIGN OF CROSSHEAD PIN.

The crosshead pin must be placed in a position where it will create no bending moment, and will distribute the vertical thrust equally over the slipper block. This being so, there only remains one place for it, and that is the intersection of the line through the cylinder and piston rod, and a line dropped vertically from the centre of the slipper block. Its position having been determined, it must be so dimensioned as to resist shear and bending moments on it as transmitted to the connecting rod; it must be of large enough diameter to reduce the intensity of pressure on it to within certain limits; and it must be short enough to allow for the side twist which is present at times on locomotives. It must always be of sufficient volume to absorb and conduct the heat of friction, and be so prepared as to give little trouble when running.

Crosshead pins are usually made of high grade steel or case-hardened wrought iron and sometimes, where the pin is part of the crosshead casting, of cast iron. They are made flat top and bottom to give clearance for the oscillations of the brass and to leave a bearing where the thrust comes. Thus:—



Locomotive wearing parts must be so designed that they can be readily adjusted to wear. In crosshead pins the wear is usually taken up by wedging the brass bushes together. Now, the greatest pressure comes on the front and back of the brasses; and as these are closed together the sides have to be eased off with file or scraper. This is the reason that pins are often made of elliptical snape, and the brasses are always eased off before being put into place.

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Knowing the maximum thrust on the connecting rod, and the area of the surface bearing it, we can easily determinte the intensity.—See "Table II."

TABLE II.

A COMPARISON OF INTENSITIES

Class of Engine	Area of Single Sliding Surface.	Force "S"	Max. Intensity on Slipper	Area of Maximal Brass Contact.	Force "T"	Max. Intensity on Pin.
Baldwin 14"x22	54.0"	2590#	48#/□"	9.82□"	25050#	2500#/□"
Kingston 18"x24"	90.0"	6560#	73#/□"	16.14□"	63400#	4000#/□"
Baldwin 15½"x26" Vauclain Comp	112.0"	8680#	77.5#/□"	23.57□"	93600#	3900#/□"
Morse Mogul 20"x26" stroke.	120.0"	8950#	74.5#/□"	26.6□"	78500#	3000#/□"

Forces "T" and "S" are maxima. the angle ABC being 90°. Force "T" = mP where m is a coefficient depending upon angular thrust & inertia of parts, and here taken as 1.25. When the rod, brasses receive Max. intensity of pressure, they are oscillating very slowly.

FEATURES OF DESIGN IN SIDE AND VERTICAL TWIST.

A criticism of the main features of the locomotive from a theoretical standpoint generally results in the discovery of many

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glaring malformations. The frames lack the necessary triangular brace, and there is apparently a looseness about the parts which, to the uninformed, betokens a serious lack of judgment and craftsmanship. But beware! Watching an engine as it "stands at ease" in railroad station or on roundhouse pit is a very different matter to watching it as it speeds along at 70 or 80 miles per hour—as it slackens up to leave a tangent track and turn on an 8° or 10° curve. Watch the bending of its parts, notice how nicely it hugs the rail, without a bind or buckle, riding as smoothly as can be; only now can one readily see the necessity of having this automaton made loose-jointed. Since locomotive crossheads, like all other parts, are subject to side and vertical twists there must be plenty of side and bottom clearance on their guides, and the bearings must have sufficient slack; besides both the pin and slipper block must not be made too long.

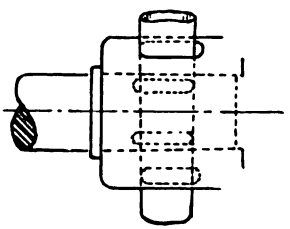


Fig. 22.

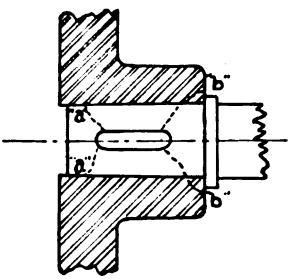
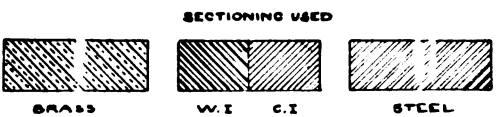


Fig. 23.



STRENGTH OF PISTON ROD CONNECTION.

There are two distinct ways of fastening the piston rod to the crosshead. Sometimes the rod end is so forged that it receives the pin on which the connecting rod and guide journals work (see fig. 16). More frequently it enters a socket which is a fixed part of the crosshead and is keyed to it (see figs. 8—15). The strength of this connection depends largely upon the amount of draw allowed for keying up, that is to say, the amount of compression that takes place between the rod and socket when the key is driven in; the ageing of the rod, it sometimes requiring a pull of 4,000 lbs. per sq. in. to start an old rod from its socket; the strength of the key;

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and lastly the strength of the socket. Sufficient to say that seldom does this part give bother, and then only when some employee, through lack of knowledge or direct negligence strains or breaks a part. For instance, a common sight in any railroad shop is to see a mechanic driving in a key with a five ton blow, when a little grinding or filing of the tight part would have done the work far better.

The usual method of connection is shown in fig. 22. Here the pressure of the key on the socket and the opposite pressure of the rod end in the socket hold them fixed.

Breaks may be caused by lack of metal, but they are more frequently the result of misfitting or misdriving. See fig. 23. The key may be broken or the socket may break out in triangular pieces as at "b, b" when the rod does not fit tightly into the socket, and as a consequence gives rise to a "bump." Or else, if the key is driven in too hard, the rod end may break at "a, a."

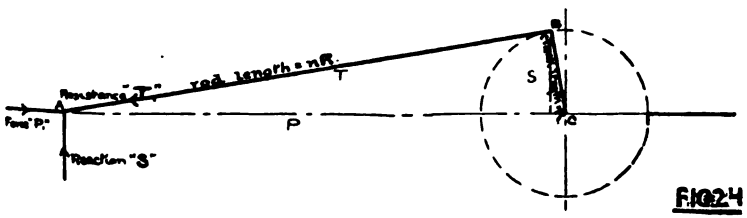

FIG 24

CONCLUSION.

We have now followed the development of the crosshead from its earliest form, to its most modern design. We have studied the main features of its construction, and looked into the comparative strength of its details; perhaps it would not be out of place to here make a small forecast. The index of modern engineering development points us to that stage where reciprocation shall have become a dead issue, and where rotation will appear in each and every form of motion. The advent of the steam turbine to marine and stationary engines only precedes its advent to locomotion. In such an era, the crosshead will have passed into history, and the many integrals of work now absorbed by it in friction shall be reckoned with as useful motive power.

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The following papers were read at the Annual Meeting, January 24th to 26th, 1905:—

PAPER No. 219,

CONSTRUCTION OF CANADIAN NIAGARA POWER COMPANY'S 100,000 H.P. HYDRO-ELECTRIC PLANT AT NIAGARA FALLS, ONT.

By CECIL B. SMITH, Ma.E., M. Can. Soc. C. E.

When the writer became Resident Engineer for this Company in August, 1901, he found that the location of the works and discharging tunnel had been already decided upon, and a shaft for tunnel construction partly sunken, and, under directions from Consulting Hydraulic Engineer Herschel, the turbine units were being given preliminary study by Escher, Wyss and Co., who also finally designed them.

Aside from the tunnel, which evidently should be built at once of full capacity, the construction then authorized was for a canal of 50,000 h.p., with temporary cribbing on the south side, a wheel pit for 50,000 h.p., and machinery and power house for 30,000 h.p.; but the company in 1902 decided to build the canal for 100,000 h.p., the wheelpit for 110,000 h.p. (one 10,000 h.p. unit as a spare), to erect a power house for 50,000 h.p., and equip it with machinery to the same extent; and this plant, along with conduits for carrying underground cables to Niagara Falls, N.Y., and to a transformer station for 25,000 h.p. outside Queen Victoria Niagara Falls Park, is now practically completed, and is in partial operation.

COFFERDAM.

Some hazardous and approximate soundings had been taken in the Niagara River at the canal entrance, but they gave assurance that the depth of water adjacent to shore was sufficient without extending operations very far out into the rapids, and a cofferdam was built on the location shown on Plate 1., which also gives details of the cofferdam itself.

It will be noticed that these cribs, if placed separately, would have been in rather unstable equilibrium, and the contractor accordingly sunk them in pairs, with turnbuckles in place, using temporary binding timbers to hold each two cribs in correct relative

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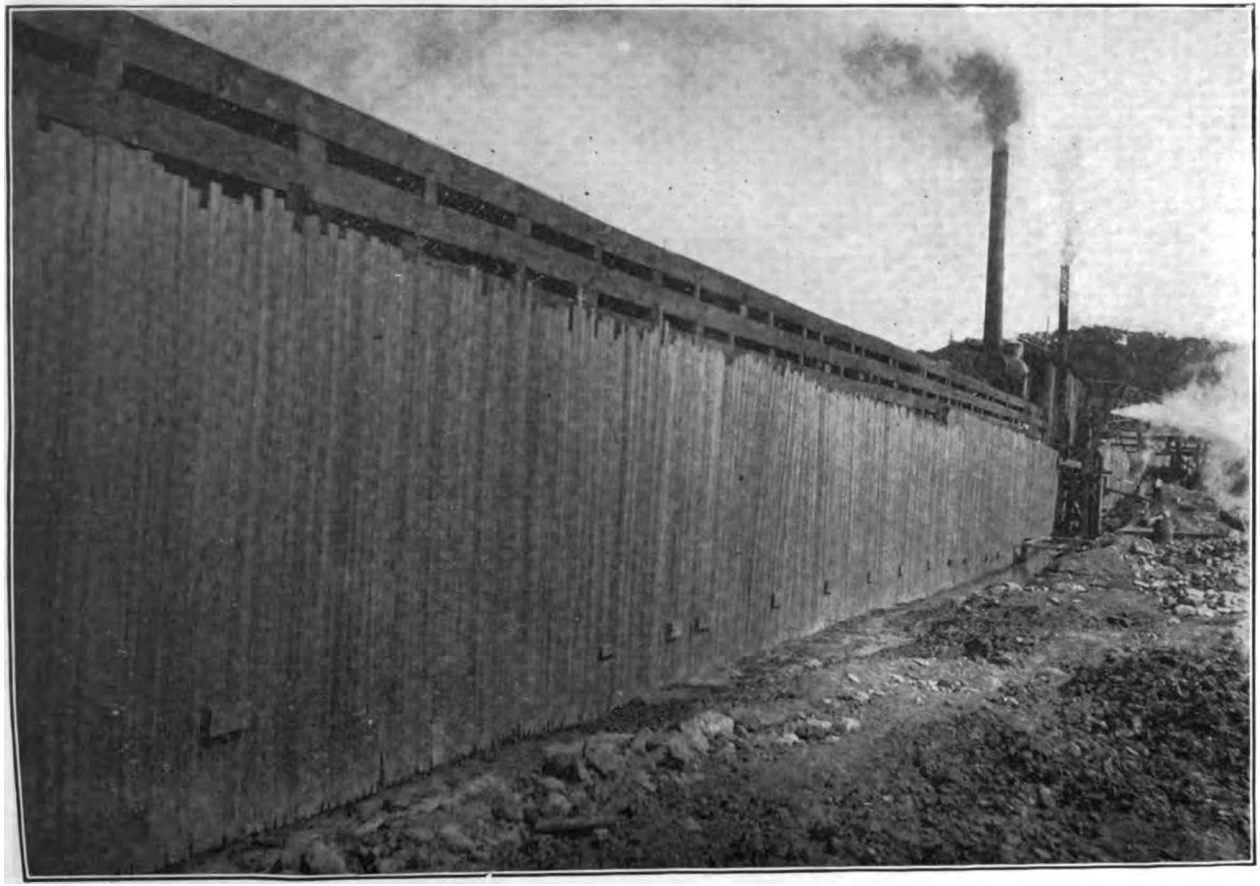

INSIDE SHEETING ON COFFERDAM.

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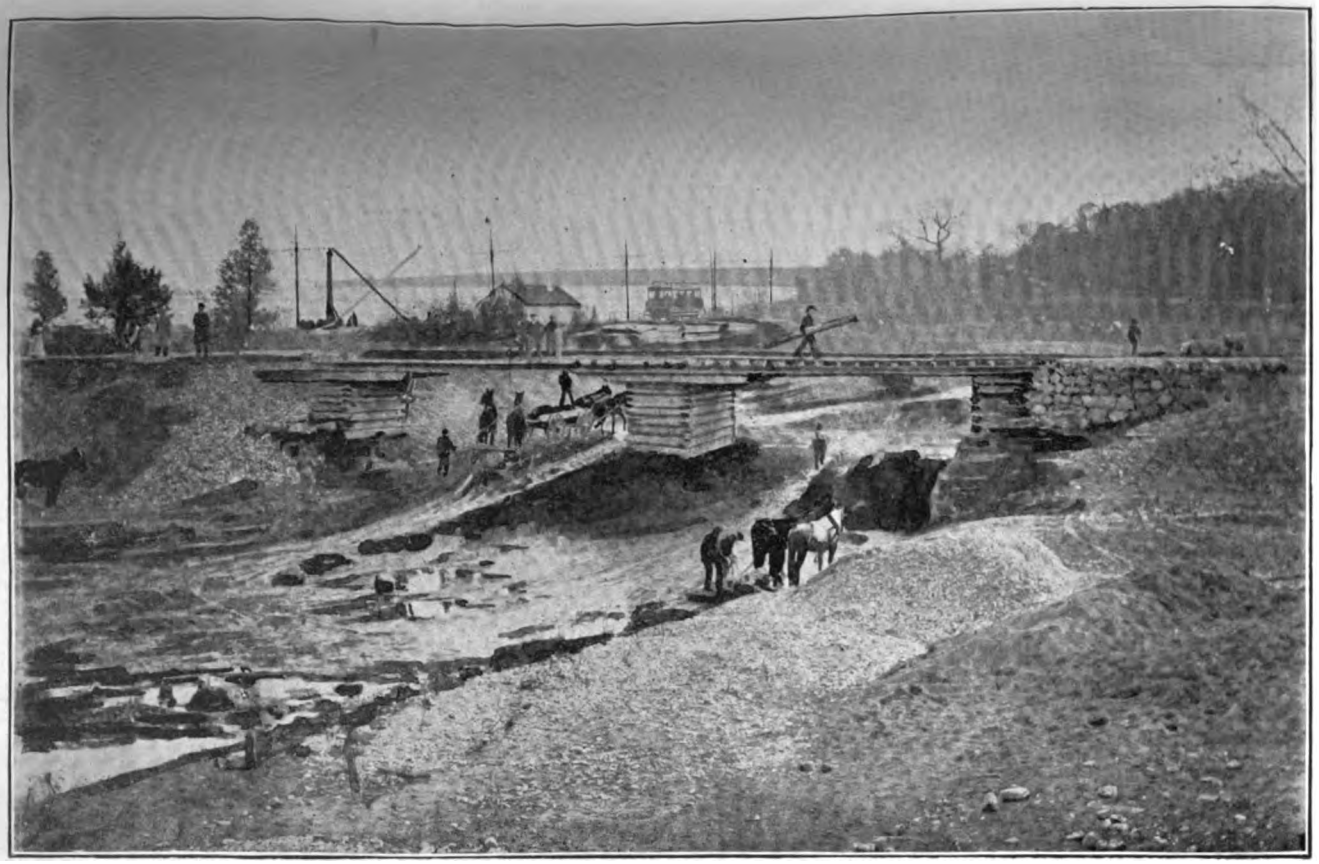

PRELIMINARY OPERATIONS. SITE OF PRESENT POWER HOUSE.

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position until sunken into place, after which these timbers were removed by divers.

The soundings for each crib were taken from a platform extending out over the water from the cribs previously placed, and the bottoms of the cribs were framed upside down, so as to fit the inequalities of bottom, denoted by the soundings. A floor for sustaining the rock filling was also placed in each crib as nearly as possible to the bottom, and the cribs were partly loaded before being floated into place.

In order to hold on to the cribs when placing them in a current of 10 to 12 feet per sec., several lines of wire rope operated by hoisting engines were used, and only one mishap occurred, when the bottom of the large corner crib was torn off. It was found advisable to add vertical binding timbers, not shown on plan, when cribs were to be placed in the heavy current. These are being found of advantage also during the removal of the cofferdam.

The puddle used was composed of about 2-3 gravel and 1-3 clay artifically mixed, as a natural mixture could not be obtained within a reasonable distance, and this mixture was found to fall quickly into place whenever leaks opened up, and could be rammed into a perfectly water-tight mass. It was found best, however, to keep the puddle wall well below water level on one side, so as to enable leaks to be promptly reached and the puddle to settle quickly.

The continuous decking was built in place as soon as cribs were filled with rock, and being tied across by timbers above water and turnbuckles below, the cofferdam acted as one mass.

In placing tongued and grooved sheeting, it was broomed down by hand mauls on to natural bottom, and fitted snugly around timber ties and turnbuckles, after which all openings at bottom, located by divers, were made tight by piling bags of rich cement mortar, and ramming them into the apertures.

When the cofferdam was pumped out by a battery of 12" 10" and 8" centrifugal pumps lifting about 10,000 gallons per minute, it was found that there was, even after temporary leakage through puddle had been cut down to nominal proportions, a heavy flow of water through the boulders and gravel lying between the cofferdam and solid rock, and as this would have had to be handled for over two years it was considered advisable to take steps to stop it, and a puddle trench was sunk to rock at each end of area unwatered, being carried in each case from shore to adjacent points on inside of cofferdam. The cofferdam proper was sheeted on inside between these two puddle cut-off walls, with double tongued and grooved sheeting extending from above water level down to solid rock, layers of tar paper being placed between the two layers of sheeting, and in order to seal the bottom a toe of rich concrete was carried along

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the bottom, being tied to the rock by thoroughly washing the surface of same, and spiking a heavy line of timber, about 12" above the bottom, to the sheeting.

This interior sheeting held the pressure of water against it until torn off when letting water into the canal, and the whole leakage was cut down to about ½ of the capacity of one 8" pump, during this period of over two years.

Bridge.

The original intention of the company was to build a steel bridge across the entrance canal, to carry the tracks of the International Railway Co., and to provide width for a park drive and a sidewalk, and the plans approved by the Park commissioners showed this class of bridge.

When, however, it was decided to build the whole canal at once, the company and its engineers decided that the style of construction to be used for canal walls, power house, etc., demanded a bridge in keeping, and accordingly a stone and concrete bridge 55 feet wide, composed of five spans of 50 feet each, and costing nearly 100% more than a steel bridge and piers, was designed and built. Plates II. and III. give details of construction. The most interesting feature of design was to obtain a bridge with high springings and low crowns, as the difference in level between the water of Niagara River and base of rail was very limited. This was obtained by using steel arch trusses and concrete filling; and various studies of stone parapet walls, seeking to give satisfactory proportions and chasteness of outline have, it is believed, been successful. There are five 50 ft. spans, and when building the bridge an allowance of ¼" was made for settlement, but this much has not taken place, although a curious condition has arisen of the arch rings settling slightly away from the parapet walls, which carry their own weight without appreciable settlement although two expansion joints were placed in parapet walls above piers.

Canal and Forebay.

Plates IV. and V. show the general lay out of the works and typical section of canal walls, which were carried out to the river entrance by 50 ft. curves, and from the bridge, westward, expand out into a forebay 570 feet long.

It will be noticed that these walls are second class rock-faced coursed ashlar backed with 1:3:5 concrete, and plans were also prepared showing solid concrete walls below low water, but the use of concrete as a facing to be presented to the wear of moving water ice laden, although at a slow velocity, was not approved of by Con-

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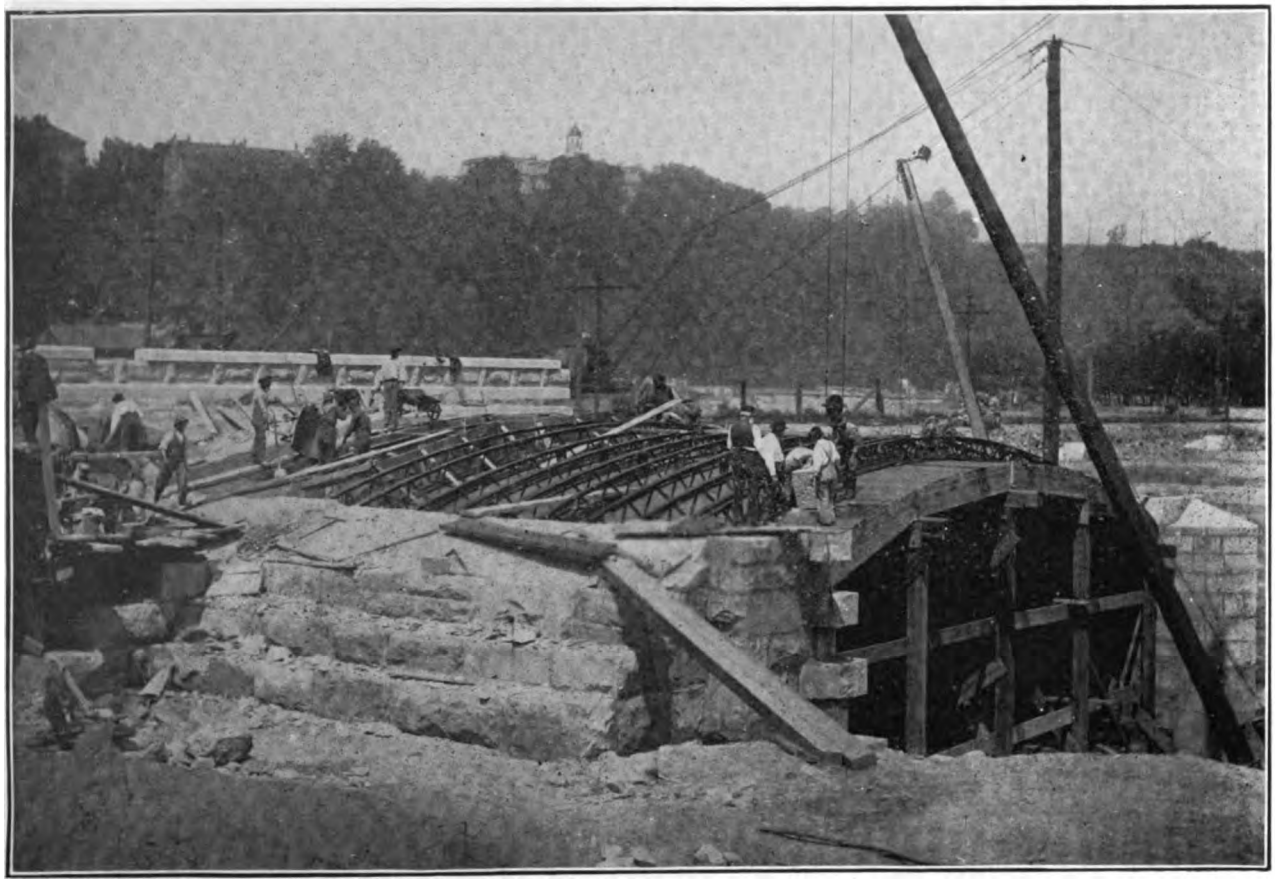

50 FT. CONCRETE STEEL BRIDGE SPAN.

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BRIDGE AND OUTER ICE RACK.

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sulting Engineer Herschel, and the present plans were adopted instead, at considerably increased cost. The same remarks apply to bridge piers and to inlet breast walls.

After deducting all losses the net effective head that this plant is designed to operate under is 136 feet with all wheels running and under this head about 8870 cubic feet per sec. will be the maximum draft.

This amount of water will pass through the bridge openings at about 2¼ feet per second with river at normal level, but in the forebay, under the same condition, the water will approach the line of submerged arches, supporting the forebay room, at only 1 ft. per second.

The Niagara river is, of course, never frozen over at the canal entrance, but after a prevailing east wind the drift ice from Lake Erie and the frazil ice formed in the rapid immediately above the works, come down in a steady flow from 50 to 100 feet wide, hugging the Canadian shore, and prepared to float into the canal whenever a flow of water creates a tendency or draft in that direction.

At first it was proposed to allow this ice to float freely into the canal and forebay, depending on the submerged arches to hold it back from the fine ice rack in front of inlets, and on the ice sluiceway shown on Plate IV. to carry it back to the river, but the writer considered a protection along the river face to be of inestimable value, and an outer ice rack was added. This rack is supported vertically by first-class masonry piers 29 feet centres, and consists of a steel footwalk with never-slip plates and another steel beam some 8 feet lower; these carry 2" rods spaced 12" centres, extending 4½ feet below and 4 feet above meanwater level, and sloping at 30° with the tops down stream. This rack will keep all heavy ice out, and the swift current will roll it along the sloping rods, and should it be found desirable a steel curtain can be suspended outside the rack and down to 3 or 4 feet below water level, thus shutting out floating fine ice, but it is not expected that frazil ice can be kept out of the forebay, as it comes down the river mixed in the water from top to bottom.

At the north end of the forebay there is a weir with three 16 feet openings, two outside and one inside the forebay room, and a fall of nearly two feet can be utilized in the winter for the purpose of creating a cross current in the forebay, thus tending to draw the floating ice back into the river, but the writer does not believe that the effect of this weir will be felt for any great distance away from the north end of the plant, although by carrying lines of floating booms diagonally across the forebay a large amount of floating ice can be poled toward the weir and thus

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passed back to the river. When not in use the weir will be closed by steel lift gates to above the water level of the canal.

The ice protections thus far mentioned will not keep back frazil ice, but no doubt the slow current in the forebay will allow a large proportion to rise to the surface, while the remainder will pass under the submerged arches into the forebay room, where there is a continuous line of fine ice racks resting at a 30° slope against the main inlet or breast walls.

These racks are carried on a steel framework, and are composed of 3″ × ⅜″ bars on edge, spaced 1 13-16″ centres, built into groups 3′ 6″ wide, by three tiers high; the bottom tier is 3′ 0″, the centre 11′ 0″, and top 9′ 0″ high, the centre ones being movable and capable of being raised up to the top, and of being held there by hooks designed for the purpose.

The functions of an enclosed forebay room will vary with the direction of current approaching the power house, and whereas this direction is parallel to power house No. 2 of the Niagara Falls Power Company, it is practically at right angles to that of the plant now being described, and therefore all floating and suspended ice adjacent to the submerged arches will, in time, pass under them and enter the forebay room, to be dealt with there by means of a travelling forebay crane, and men using rakes and poles.

However, even in this power house, an enclosed forebay room is of great value, affording comfortable quarters for men fighting ice in stormy weather, and moderating somewhat the temperature of the ice rack.

In extreme cases the centre sections of the ice rack are raised up, and the accumulations of fine floating ice and frazil are allowed to pass through the wheels, whose large ports will take care of considerable quantities of fairly large ice without any injury to the bronze runners.

The water, after passing the fine ice rack, enters 18 ft. openings in the masonry inlet walls, thence passes through cast iron penstock mouth-pieces which are elliptical (18′ × 12′) at the outer end and 10 feet in diameter at the inner end where they pass through the main wheelpit walls, and flows into the upper elbows of the main penstocks. During ordinary operation the movement of water is controlled by head gates set in lubricated cast iron groves in the inlet walls, and operated by lifting screws, a box girder fastened onto the steel columns of the power house, and a 20 h.p. 125 Volt D.C. motor mounted on this girder, and for the purpose of filling the penstocks, so as to release the pressure on the gates, small hand operated wicket gates have been inserted in the main gate bodies.

Outside of these lift gates two sets of stop log grooves have

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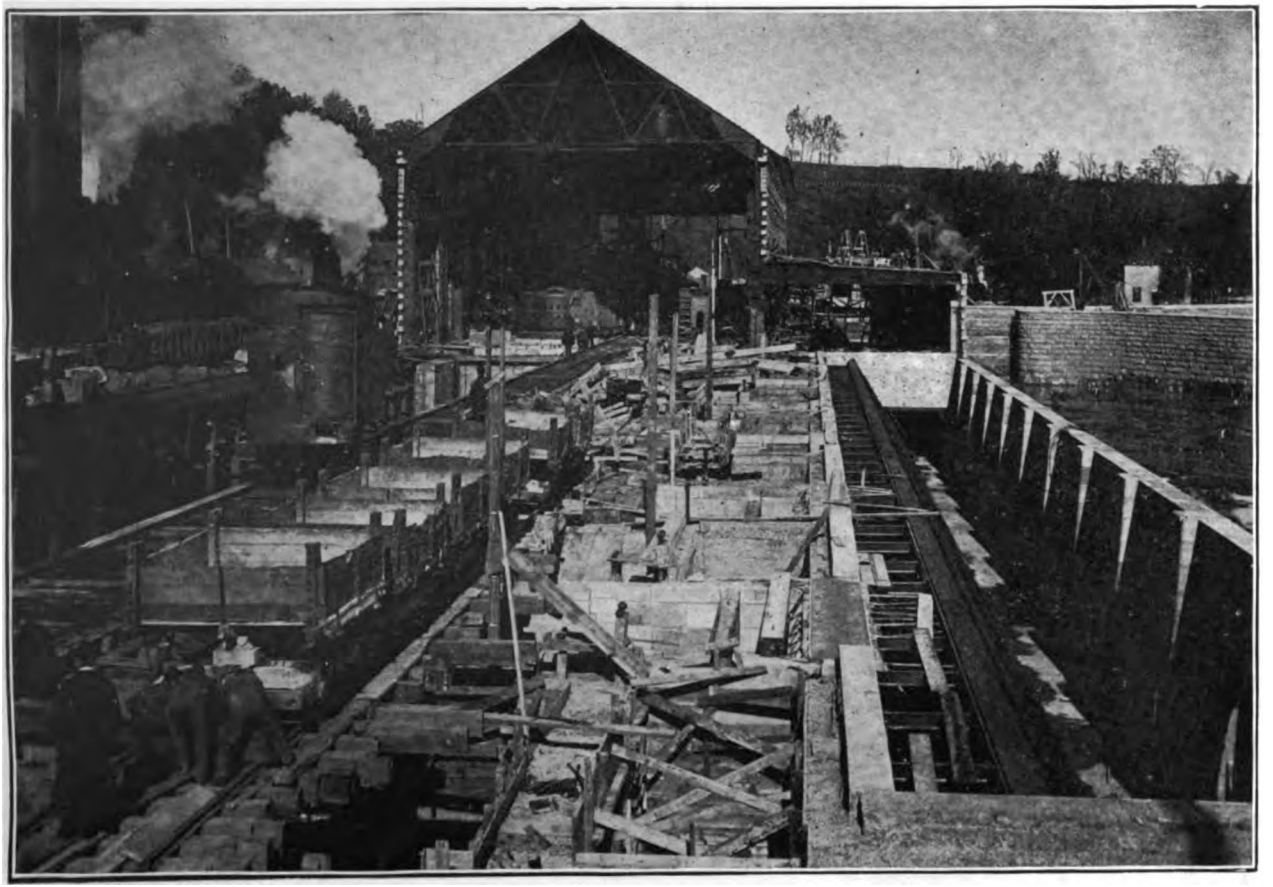

GENERAL VIEW SHOWING SUBMERGED ARCHES AND ICE RACK.

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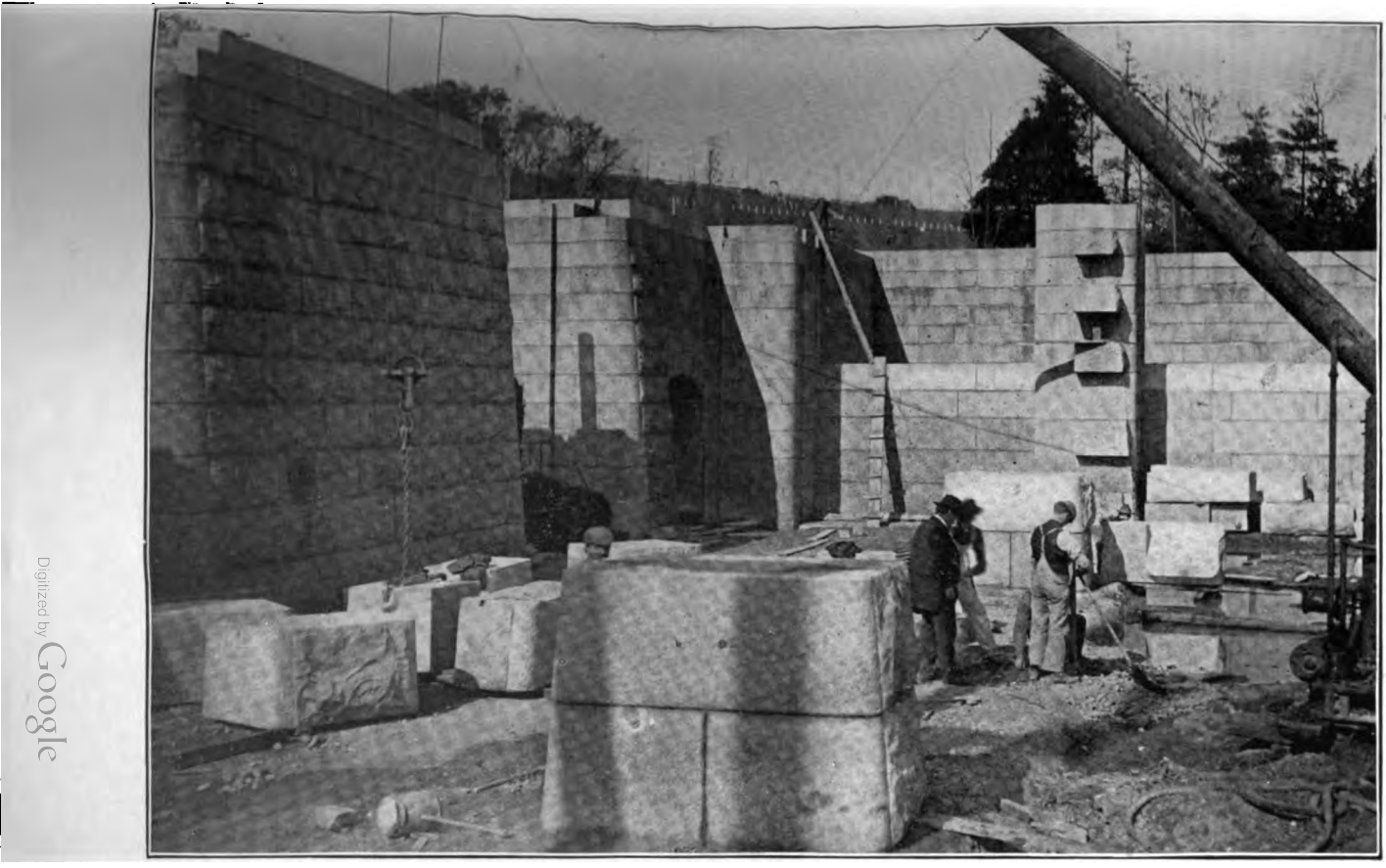

MASONRY AT N. W. CORNER OF FOREBAY SHOWING OVERFLOW WEIR.

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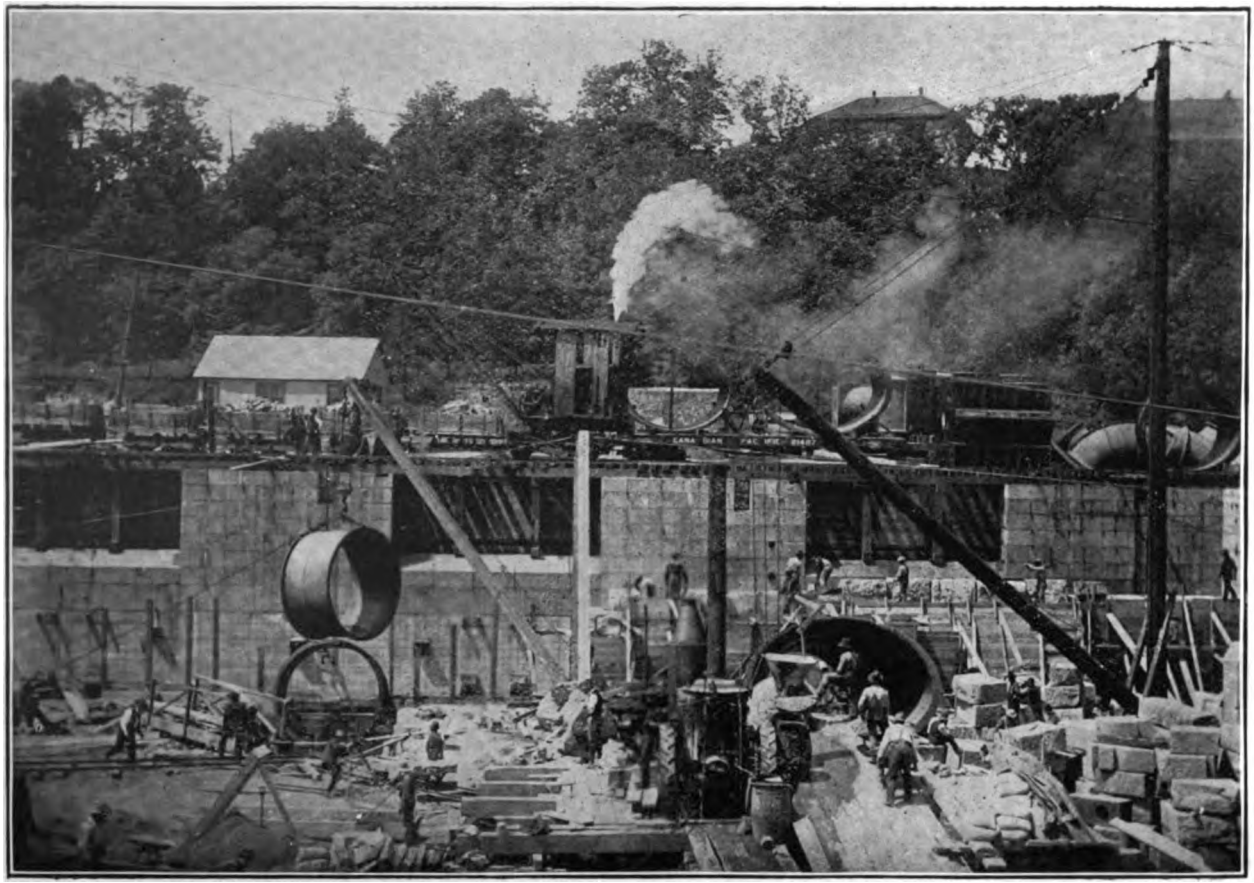

VIEW OF WHEELPIT LINING WALL, PLACING MOUTHPIECE RINGS.

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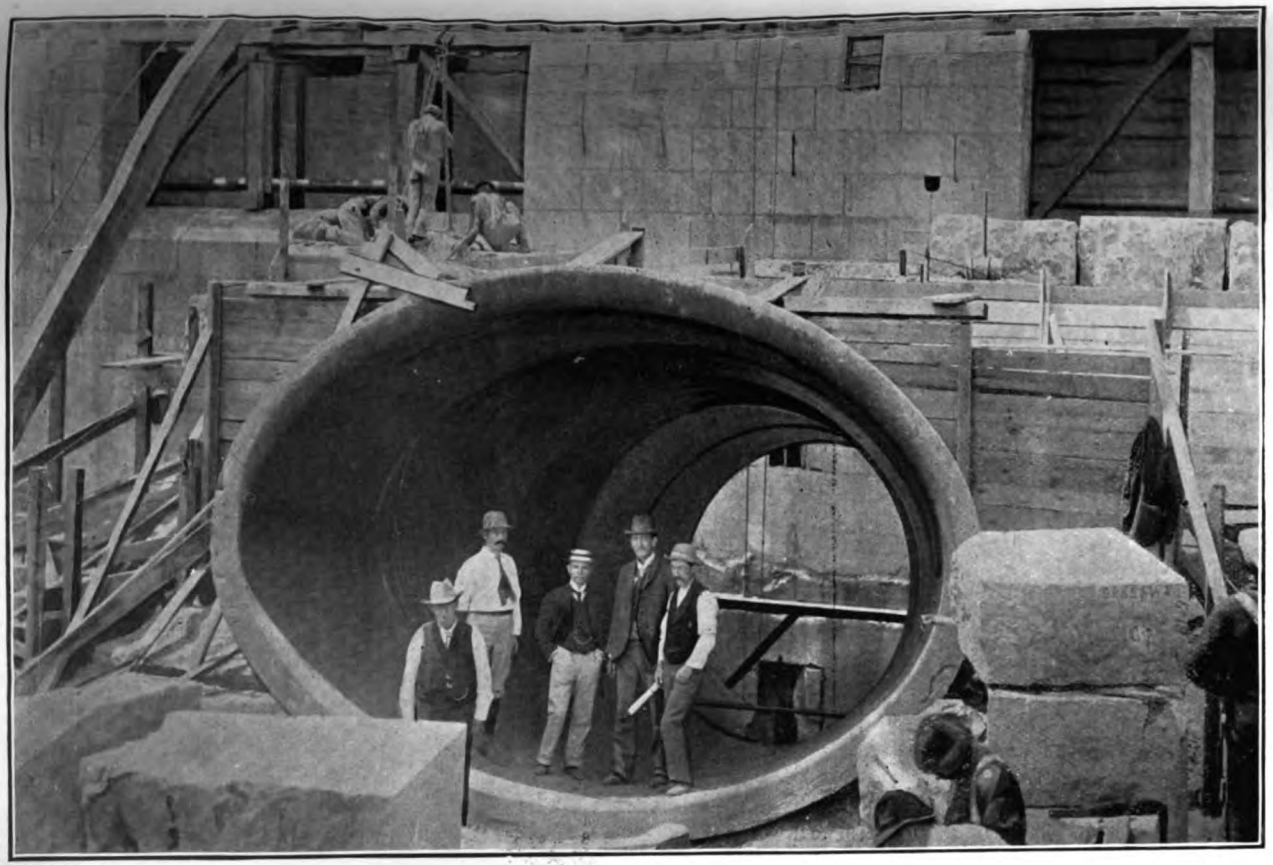
VIEW OF WHEELPIT LINING WALL. PLACING MOUTHPIECE RINGS.



ELLIPTICAL MOUTHPIECE FOR UNIT NO. 2.

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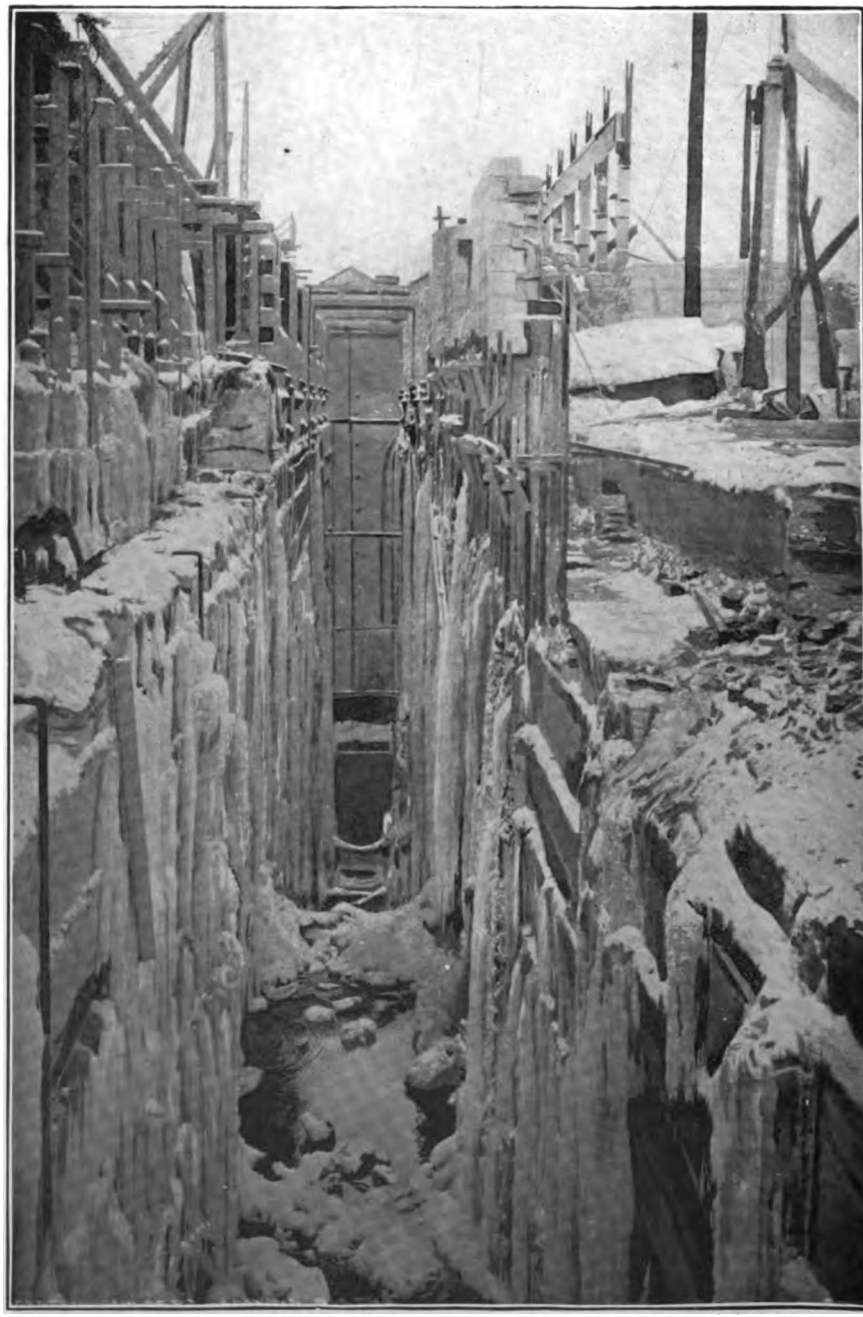

A WINTER SCENE IN WHEELPIT EXTENSION—COMPLETED PIT IN MIDDLE DISTANCE.

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been cut at each inlet, so that in case the lift gates require unwatering stop logs can be inserted.

Wheelpit.

This pit, which is 570 feet long and 18 feet wide, after lining, was excavated through 15 feet of boulders and gravel, 100 feet of limestone, and 50 feet of shale, the sides being separated, before blasting, by channelling. The channelling machines are self-propelling and have a travel of about 12 feet, the cuts being carried down in 6 foot benches, having 6″ batter. After blasting and excavating a bench, the channelling was again proceeded with, an off-set of 6 inches being required for clearance.

For the reception of numerous castings, draft tubes, etc., a great amount of excavation was required in the form of recesses, and in order to do this without unduly shattering the side walls, the whole periphery of each recess was separated, preliminary to blasting, by gadding and broaching, the process being that of a drill body, mounted on a vertical column and truck, and working horizontally; by using small charges of dynamite, these detached masses of rock were then blown out, leaving the adjoining walls usually intact.

When the wheelpit for first installation of 50,000 h.p. was about two-thirds excavated, the tunnel excavation had been completed to the wheelpit, and in order to expedite the completion of the plant the writer urged that the general design should be changed, substituting two branch tunnels, turbines resting on the solid bottom, lower penstock elbows ditto, and draft tubes leading from the wheel cases to the branch tunnels, which would admit of tunnel excavation being pushed forward, and wheelpit excavation being completed four months sooner than would be the case if the lower part of the wheelpit was to constitute the beginning of the tail race.

The merits of this method had already been suggested by Escher, Wyss and Co., the simplifying of the lower penstock elbow and greater solidity of the turbine unit when in operation being evident, and, in passing, it is interesting to note that the Toronto and Niagara Power Co. has adopted this identical design for the plant they are now building. However, the view of the consulting hydraulic engineer was against the change and in order to hasten the completion of the wheelpit excavation which, on the lower levels, is very much cut up by various checks and recesses, it was decided to carry forward the tunnel excavation immediately underneath, and bring down the wheelpit excavation on the tunnel roof.

This process was fairly successful until about two-thirds completed, when the blasting from above and below had so weakened and

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opened up the remaining shale that wheelpit water commenced to leak into the tunnel, throwing excessive loads on the tunnel roof, and necessitating increased timbering at this place, until finally tunnelling operations had to be abandoned, and the remainder of the pit excavated in open cutting as originally intended.

The after effects of this effort to hasten operations were that the sides of the wheelpit, where excavated by tunnelling, were badly shattered, and before the brick lining could be placed large masses of shale broke away, so that as the brick lining was being put in it was necessary not only to fill up these enormous cavities with concrete. but the walls had to be continually watched and scaled down for fear of accidents.

As soon as excavation was well forward it was decided to take measurements for anticipated movement of the rock walls, and the following table will serve to illustrate what actually took place, it being understood that excavation was being carried forward continuously from March, 1902, to June, 1903, and that the measurements given are only a few of those taken.

TABLE OF WHEELPIT SQUEEZE

Measurements taken between steel plugs at centre of a pit 275 feet long. and at a point 15 feet below rock surface.

Date.	Total width.	Depth of pit at time of measurement.
July 8, 1902.	20′ 11 1-2″	35 ft.
Aug. 23, 1902.	20′ 11 1-16″	50 ft.
Sept. 10, 1902.	20′ 10 15-16″	55 ft.
Oct. 13, 1902.	20′ 10 13-16″	65 ft.
Nov. 13, 1902.	20′ 10 13-16″	75 ft.
Dec. 18, 1902.	20′ 10 13-16″	85 ft.
March 6, 1903.	20′ 10 13-16″	100 ft.
April 7, 1903.	20′ 10 12-16″	110 ft.
May 8, 1903.	20′ 10 25-32″	125 ft.
Oct. 15, 1903.	20′ 10 7-16″	full depth.

Giving a total of 1 1-16 inches, although at lower levels a movement of 1 1-2 inches was observed between November, 1902, and October, 1903.

Not the least curious feature of these movements was the fact that the east side next the river moved about twice as much as the west side adjacent to higher ground. But the most noticeable fact of the table is that the movements, which had practically ceased by March 1903, had again become serious by October, 1903, and this had been caused by the excavation of the wheelpit extension 300 feet

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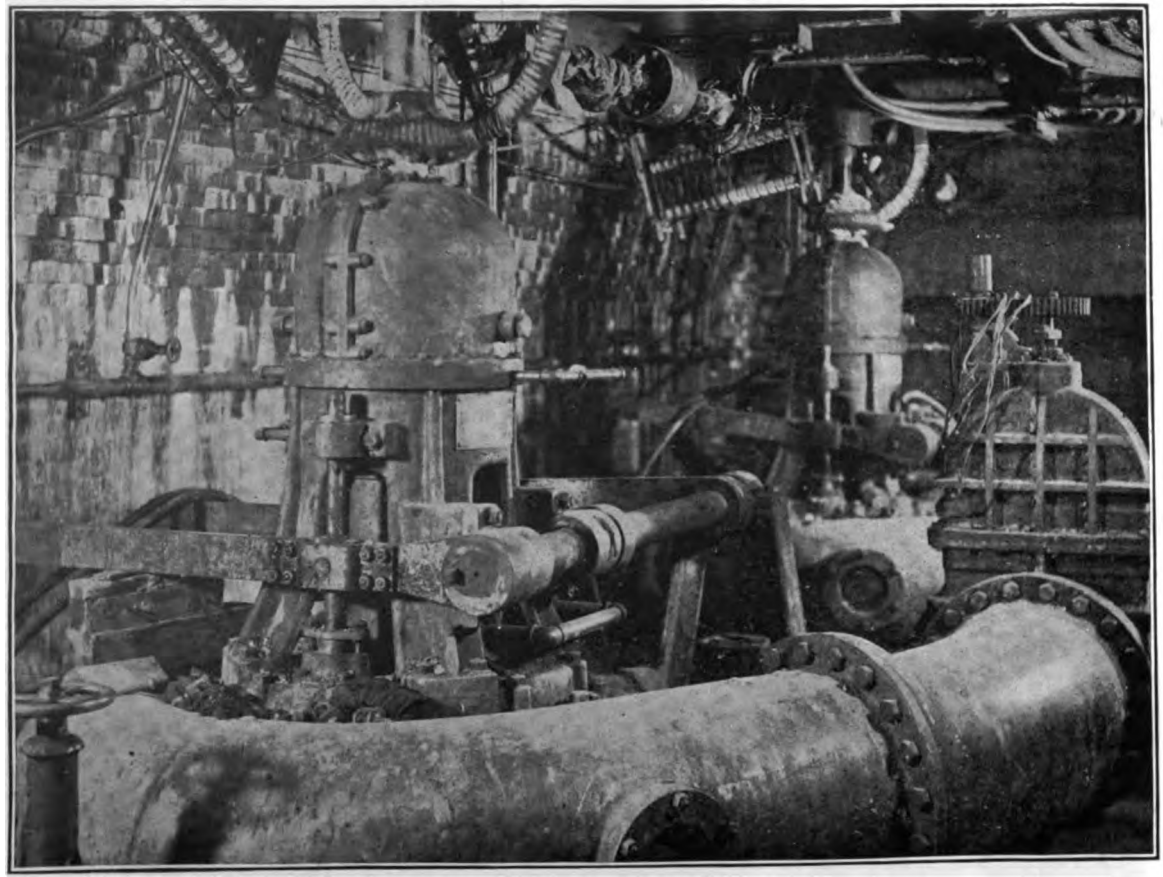

EXCITER TURBINES.

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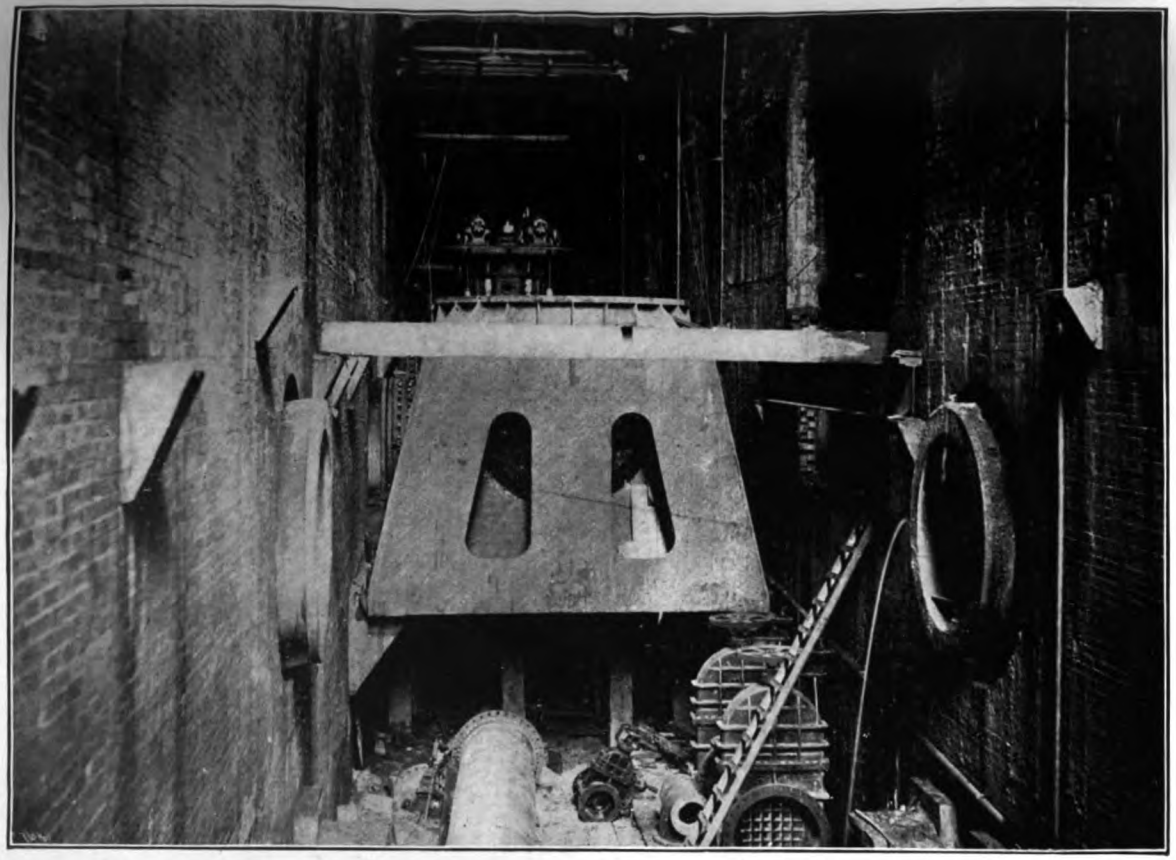

CAST STEEL LOWER ELBOW OF PENSTOCK.

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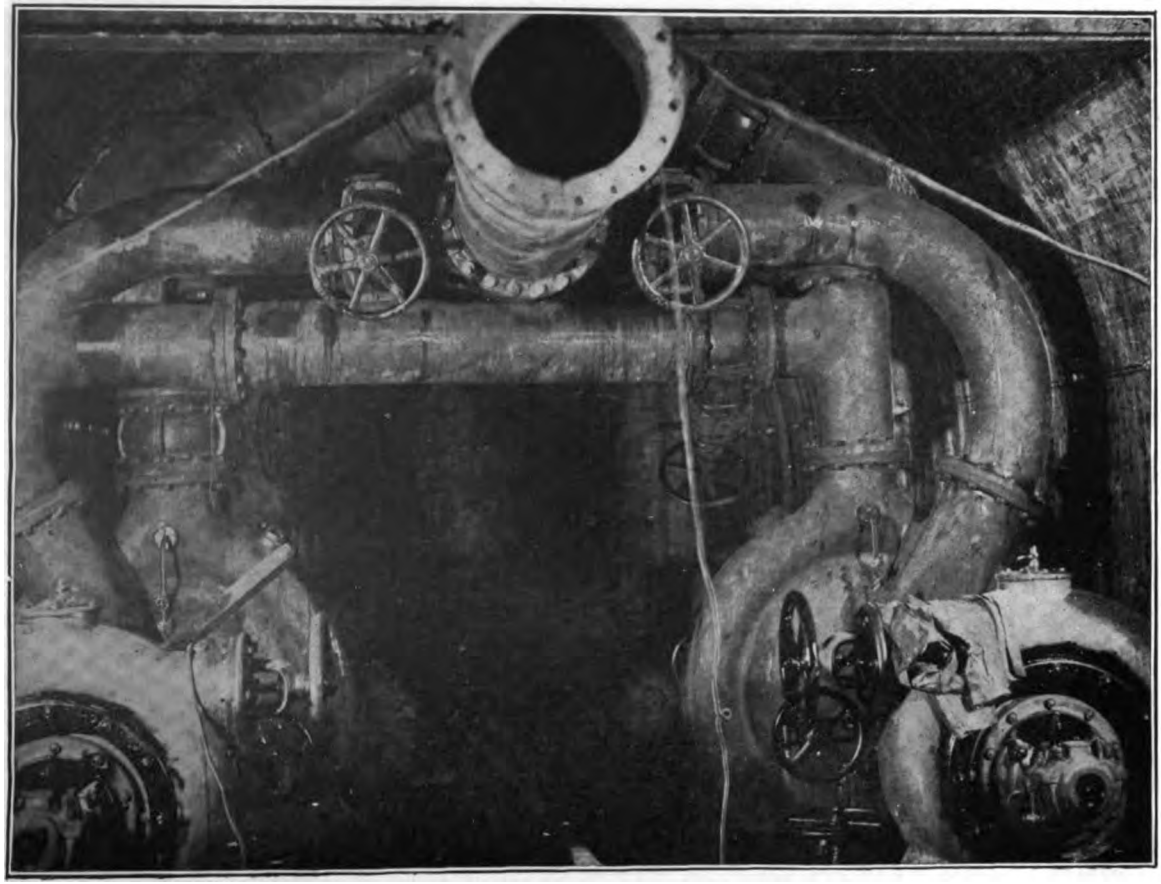

CENTRIFUGAL PUMPS.

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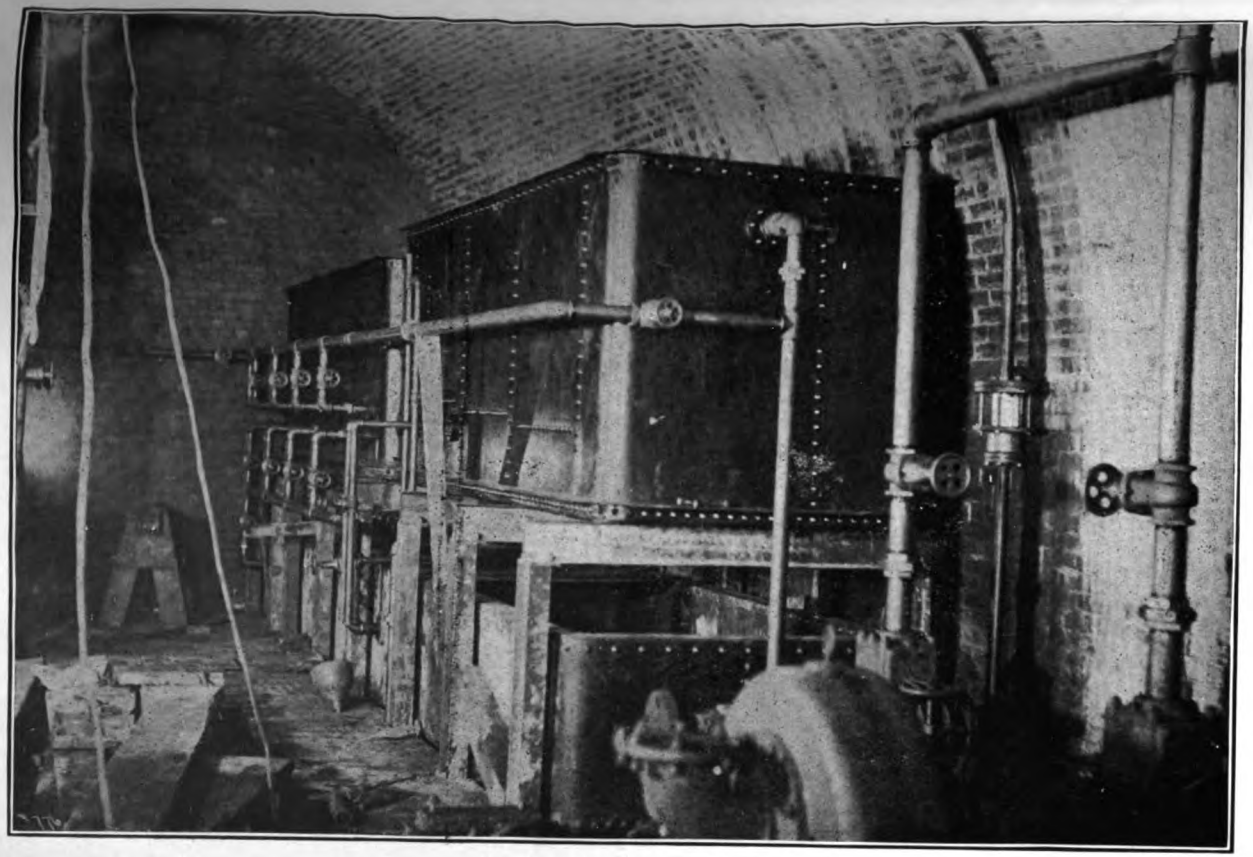

A GROUP OF OIL TANKS.

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further, freeing one end of the rock walls. This is further shown by measurements on thrust girder castings of west wall, which had been set in September and October, 1902. It will be seen that the movements had practically ceased in March, 1903, but again commenced as soon as the excavations of the extension to pit was carried down for some depth.

The first generator arch built was at unit No. 4, and during the summer of 1904 it became evident that it was being severely squeezed, and even after several heavy arches had been built, the masonry lining walls of wheelpit at the level of the springing of the arches showed slight movements. It was therefore decided to put in a few heavy cast iron struts across the pit at units No. 4 and No. 5, thrusting against cast iron strut bases, which had been provided in over 20 places in anticipation of trouble.

Four struts at unit No. 5 and two struts at unit No. 4, each of about 250 tons safe capacity, seem to have completely stopped the squeezing movement.

TABLE OF WHEELPIT SQUEEZE

Total movements of west wall at thrust girder level.

Date.	Unit 1.	Unit 2.	Unit 3.	Unit 4.	Unit 5.
Dec. 18, 1902.	— 1-16″	1-4″	7-16″	7-16″	15-32″
Jan. 27, 1903.	— 1-16″	7-32″	11-32″	7-16″	15-32″
Mar. 6, 1903.	— 1-16″	3-16″	7-16″	11-32″	9-16″
Feb. 13, 1904.	+ 1-8″	1-32″	5-8″	1 1-8″	1″

TABLE OF WHEELPIT SQUEEZE

At unit No. 3 after struts had been placed at various levels at Units No. 4 and No. 5.

Date.	Thrust Deck.	Turbine Deck.
Nov. 14, 1904.	18,882 ft.	16,451 ft.
Nov. 23, 1904.	18,881 „	16,447 „
Nov. 28, 1904.	18,884 „	
Dec. 6, 1904.	18,882 „	16,450 „
Dec. 13, 1904.	18,884 „	16,446 „
Dec. 21, 1904.	18,884 „	16,445 „
Jan. 2, 1905.	18,883 „	16,442 „

The lining of the wheelpit, which consists of 24 inches of solid shale brick from invert up to rack deck, and 12 inches of solid shale brick backed by 4 inches of hollow brick thence to top, is

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anchored to the rock walls by anchor bolts with wedges and having large plate washers embedded in the brick work, and, as the work was laid with a shove joint with one to three cement mortar, it is practically watertight, the leakage through the seams in the rock passing into the hollow brick and down openings left in the hollow brick lining to cast iron weeper boxes at the rack deck level, the water falling from them freely into the wheelpit just above tail race level.

During the placing of the brick lining a great number of castings were placed in position. These consisted of the main and auxiliary draft tubes, which were buried in the brick walls (the bracket casting section alone of each draft tube weighing about 25 tons) and castings for supporting the lower penstock elbows, guide girders, thrust girders, and the various floors placed in the pit for purposes of operation.

These latter castings varied in weight from ½ ton to 6 tons, and extended back from the face of the wall from 3 to 5 feet, depending on the loads to be carried, while the lip or shoulder carrying the loads extended only a few inches beyond the face of the walls. These castings were, of course, hollow and were filled with concrete before being placed in position.

Accuracy being necessary, great care was taken as to height and longitudinal position. In placing all castings, piano wires on a reel carried heavy plumbobs immersed in water, and elevations were transferred from one level to another by a steel tape, which had been standardized at Washington, D.C. All work was carried to 1-1000 of a foot, and, with very few exceptions, the results obtained were found very satisfactory during the period of machinery setting.

On the east side three chambers, averaging about 40′ × 16′ × 30′ high, were built at right angles to the wheelpit and just above the level of the rack deck, which is the first floor above the water in the tailrace part of the wheelpit.

They were excavated as tunnels by top headings and benches, but being in limestone did not need timbering. The lining was the same as that of the wheelpit, and they were divided up into various levels by steel floors carried on brick ledges on the lining walls.

In the extension of the wheelpit two other similar ones are being built.

These chambers contain the exciter units, the pumps for forcing water to the transformer station, an air compressor (Pelton driven) and a system of oil tanks, filters and pumps for supplying oil to the high and low pressure bearings. The machinery in these chambers will be referred to later on.

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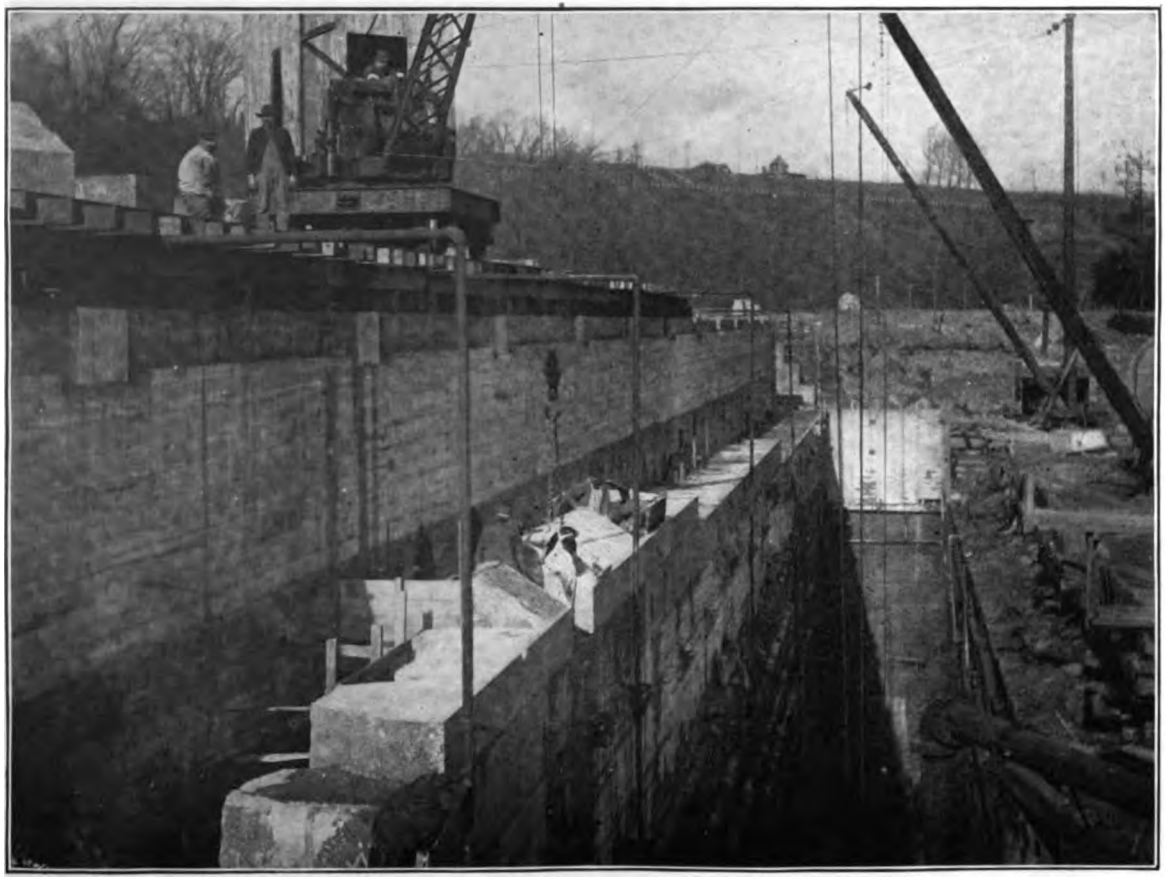

UPPER WHEELPIT LINING WALL AND POWER HOUSE WALL.

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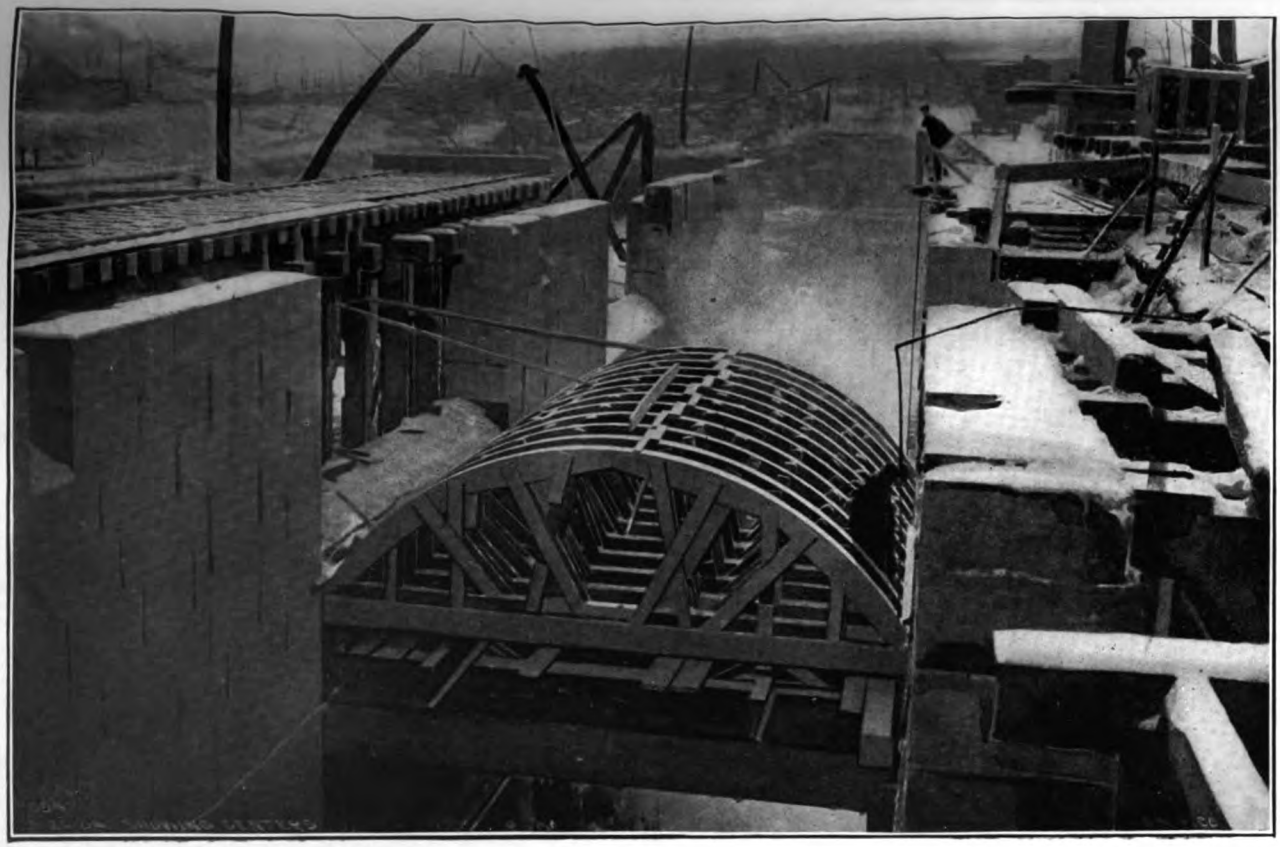

CENTRES FOR GENERATOR ARCH NO. 4.

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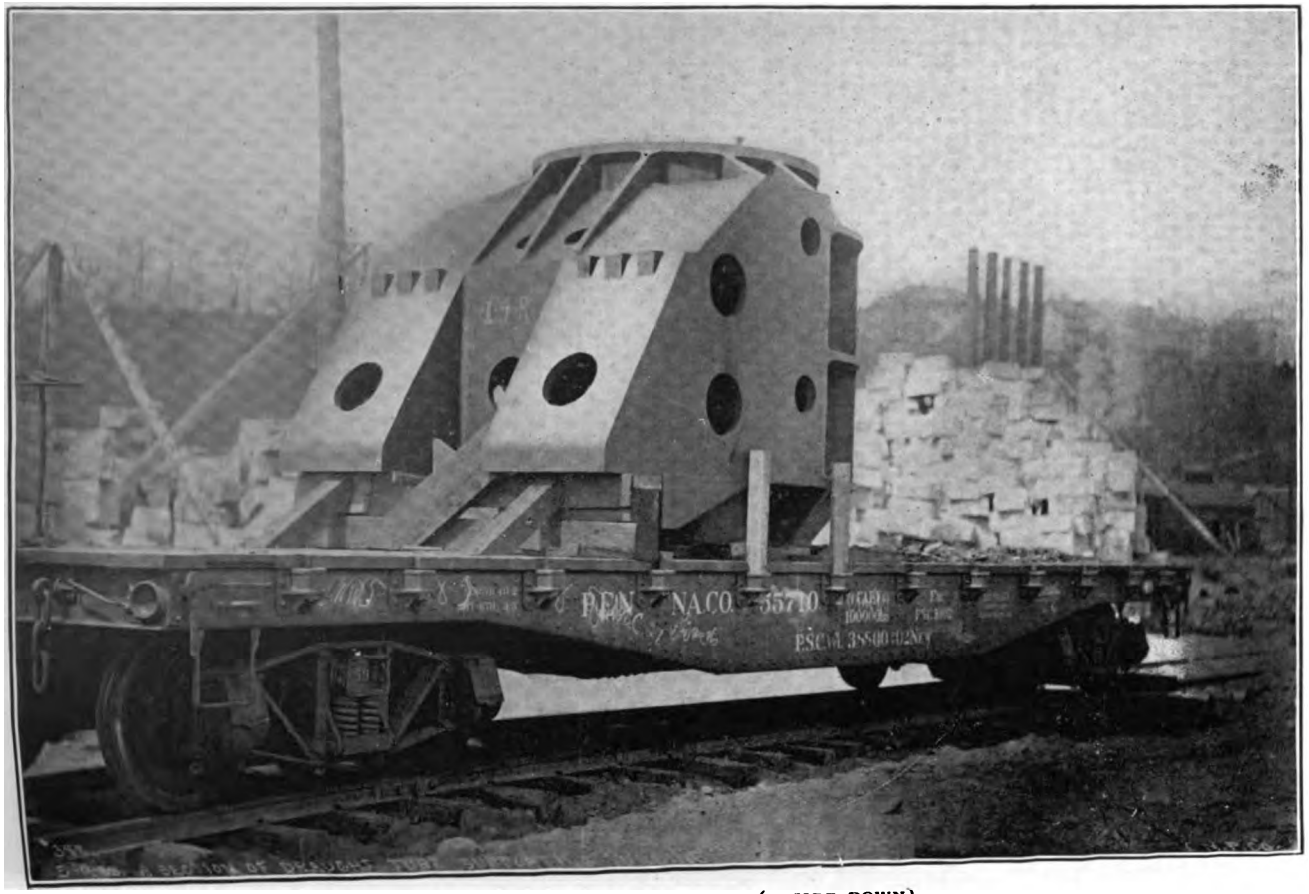

BRACKET SECTION OF A DRAFT TUBE (UPSIDE DOWN).

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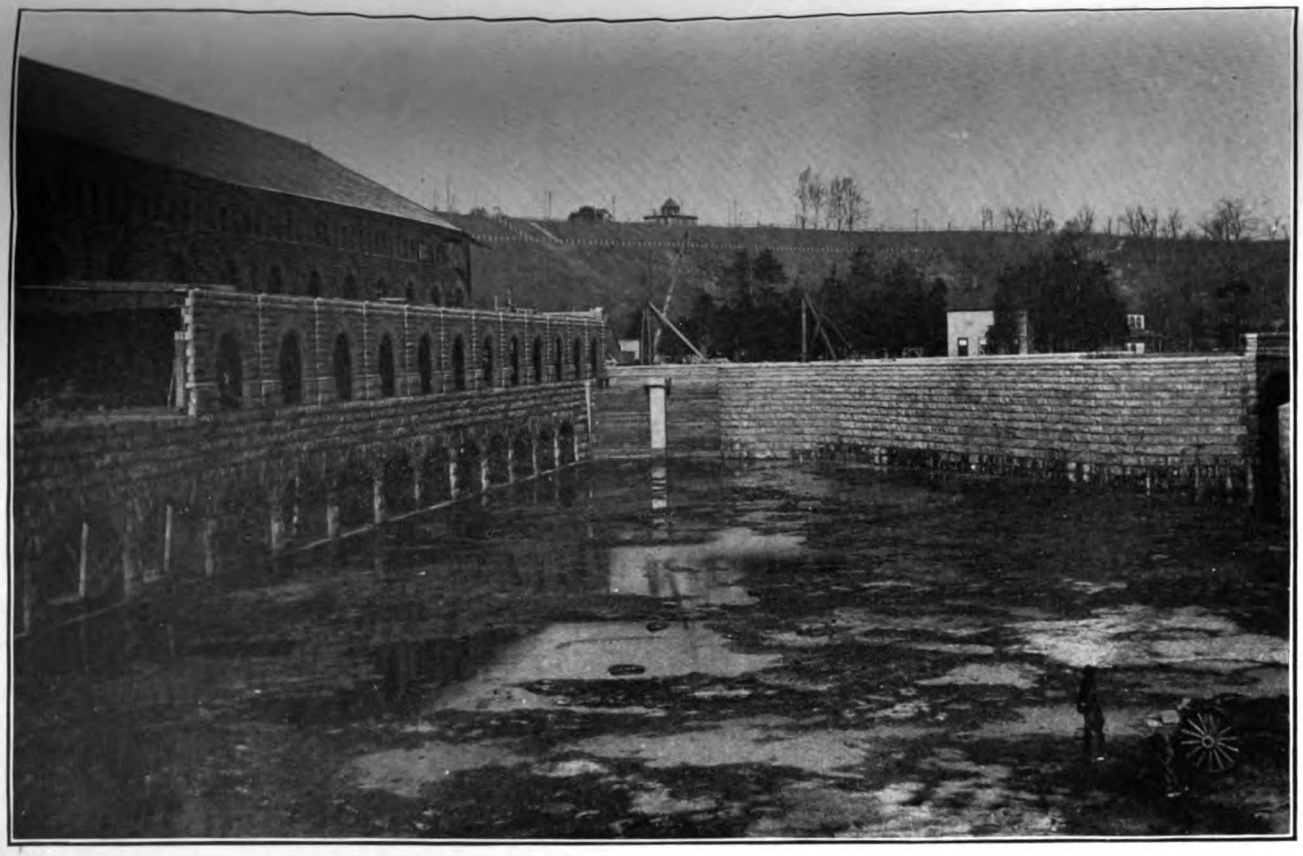
BRACKET SECTION OF A DRAFT TUBE (UPSIDE DOWN).



GENERAL VIEW OF POWER HOUSE, FOREBAY AND CANAL.

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TAILRACE TUNNEL.

The original design for this tunnel was of a section 21 ft. high, with brick lining 16½ inches thick, but this was finally modified to the present section, which is 25 feet high, and has a composite lining, the bottom and sides being of concrete, faced with 4 inches of highly burnt brick, while in the arch a brick ring with dry packing was adhered to on account of the difficulty which would have attended the building of a concrete arch (see Plate V.).

When the discharge tunnel was built for the Niagara Falls Power Company there was no exact information as to the value of the friction co-efficient for a brick lined channel of such large dimensions carrying water at a high speed, and even when the present tunnel was commenced, the United States tunnel had not yet been tested to its full capacity, nor properly calibrated, but an examination in the winter of 1902 showed the brick lining, although of a very ordinary quality, to be absolutely intact, unworn, and slimed over after seven years' use, with water flowing at about 27 feet per second. Still, to make assurance doubly sure, the brick facing of the present tunnel was made of a superior burnt smooth brick, and the section made about 20% larger than the earlier one, so that the velocity will be slightly increased as the grade of seven feet per 1,000 is continuous, and the alignment of the tunnel very favorable, consisting of two curves of long radius with direct outlet in line with wheelpit (see Plate IV.).

This tunnel is 2,200 feet long, including the headworks at portal, which consists of a square headwall 60 feet wide, 12 feet thick, and 55 feet high, extending to a depth of 35 feet below water level resting on a foundation well into the Medina sandstone; from this readwall the tunnel rises in an ogee curve for some 80 feet to the tunnel proper, and this portion is lined with 2 feet of granite, which it was considered advisable to use in place of brick, owing to the excessive speed of the water when dropping to the river level, it being understood that the invert of the tunnel at the top of the ogee curve is at the low water river level.

The excavation was carried both ways from a shaft sunk midway between the portal and wheelpit and was also carried in several hundred feet from the portal, and although the alignment was fixed from two piano wires 12 feet apart, suspended in the shaft, the instrument work at point of meeting of headings was found to be almost perfect, which must be looked on as a result of extreme care in the use of plumbobs, and taking the average of a large number of observations in this and surface instrument work.

Owing to the upper portion of the tunnel being in shale, it was necessary to carry a full timber roof consisting of 5 centred 12"

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× 12" rings four feet apart and three inch lagging, and these were put in place, along with the wall plates, as fast as the headings were driven, while the plumb posts, carried down to limestone, were inserted at the time the two benches were being taken up.

The original idea was to use yellow pine timber, but this was modified by substituting hemlock for centres and plumb posts, where the stresses would be compressive, and, although they were much abused by blasting, the result was satisfactory, owing to the absence of much water to soften and swell up the shale roof; the portion of roof adjacent to the wheelpit was subject to leakage when the pit excavation was being done just above the tunnel level, and at this point the roof timbers were badly crushed, and the centres settled several inches, the fibres of the hemlock segments being forced into one another.

The process of lining the tunnel was as follows:—The concrete invert (1:3:5:) being laid, the vitrified brick invert was placed as far as the corner specials, side forms were then put up and lagging, wedged back 4½ inches, was placed as high as the first course of brick headers. After the concrete side walls were built up to this height, the lagging was removed, and the brick facing carried up to and including a header course, after which the process was repeated to the springing, the only variation being that dry packing was used between and behind the plumb posts, in place of concrete shown on plans.

The brick arch was built in the ordinary way on full centres, and 4" × 4" lagging, a night man building in the key of the arch work done during the day, and laborers placing dry packing above the haunches and driving it home against the roof timbers, also removing centres after being in position two or three days, and bringing them forward to a new position.

After side forms and arch centres were removed, the whole tunnel was scraped clear of all mortar with sharp iron tools, leaving the surface smooth and clean. It is believed that a very low friction co-efficient will exist in this tunnel, especially when the walls become slimed over with deposits from water such as have formed on the walls of the Niagara Falls Power Company's tunnel. The shaft for this tunnel was sunk from May to September 1901. Excavation was completed December, 1902, and lining and headwall in May, 1904, after which the shaft was bricked up, and outlet excavation at portal completed during the summer of 1904.

No attempt was made to hasten the completion of this portion of the plant before the machinery installation demanded it, otherwise much greater speed could have been made.

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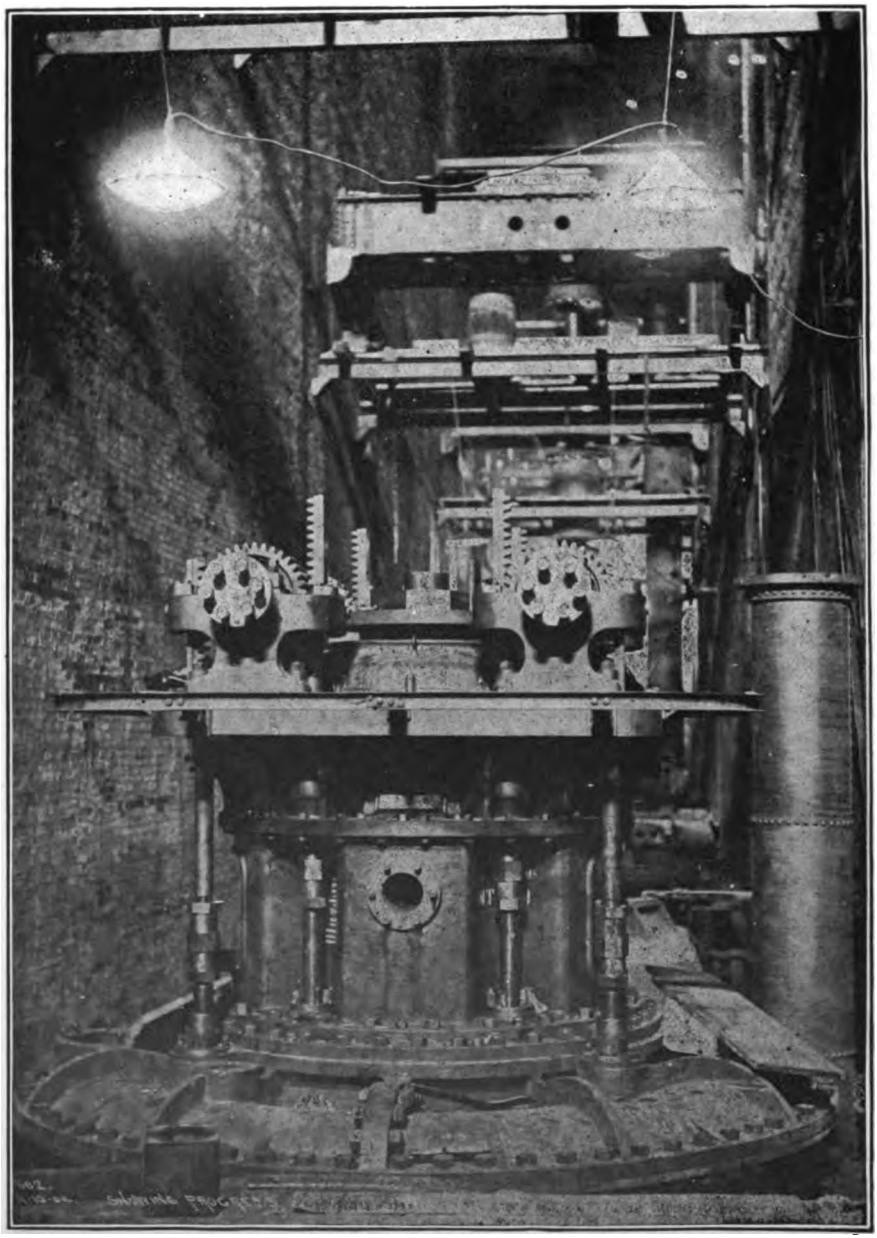

10,000 H.P. TURBINE UNIT AT BALANCING PISTON.

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Power House.

The superstructure covering the generators and switchboard, etc., is a heavy steel framed building, at present covering five 10,000 h.p. units, but the design is for a complete building 600 feet long, covering 11 10,000 h.p. units, with main entrance at the north end. (Plate VII.).

The main building is 40 feet high to the eaves, and has crane girders 31 feet above the floor, this height being necessary for proper movement of large loads from one part of the power house to another, after the machinery was installed. The proper light effect is obtained by large arch windows below the crane girders, and a series of smaller square ones just below the eaves. The exterior walls are of Queenstone gray limestone, with sufficient tooling for rich, quiet appearance; and the interior lining consists of a wainscotting of enamelled brick up to the window sills, then a belt course of green veined Vermont marble in line with the marble window sills. Above this the lining will be buff brick, which will ensure a pleasant well-diffused light. There is an arc light on each side of the power house every 24 feet.

The roof of the main power house is of steel and terra cotta tile only, the tiles being interlocking green Ludowici, pointed with mortar; and the eaves are carried well out with a slight upward curve, ending in heavy copper gutters.

The forebay room is attached to the east side of the power house, as shown on Plate VII., and has a flat steel and concrete promenade roof, with an asphalt and tile floor. It is surmounted by a stone parapet wall with 24 foot panels, it being proposed to place electric light columns and flower vases at the panel posts; while, for the purpose of throwing light into the room itself, in addition to arch windows every 24 feet, there is a wide continuous skylight in the roof adjacent to the power house; in the forebay room a 5-ton travelling crane spans the whole width, and will assist in keeping racks clean, and lifting them when necessary.

All the main window frames are metal, which leaves only the window sash, and small upper window frames of wood, so that practically speaking, the building is strictly fireproof. At the north end the main entrance door will be of bronze with carved side columns, and surmounted by a panel containing the company's seal; while stretching across the north end of the power house will be a visitors' gallery, from which the best view of the interior of the building can be obtained.

Underground Conduits.

In order to convey current from the power house two lines of conduits were constructed, of the style shown on Plate VI., one

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of which, 2,200 feet long, leads to a transformer station located outside the public park, and the other, one and a quarter miles long, extends from the power house through the park to the upper steel arch bridge. The four-way ducts are embedded in a one to seven gravel concrete, and are spaced generously so as to provide proper heat radiation, it being found that in a large group of cables the centre ones do not have the carrying capacity of the outer ones.

The manholes are also entirely of gravel concrete, and are drained thoroughly with six-inch tile, into which are carried the farm tile, laid alongside the ducts themselves; and a curtain wall divides the manholes into two parts, while a further separation in case of fire is obtained by soapstone slab partitions lying horizontally between each group of cables. The ordinary type of manhole carries the cables straight through without any appreciable bends, the plan shown on Plate VI. being a special, and the 12" water main shown is for carrying water from the pumps, located in the power house, to the water cooled transformers and standpipe situated outside the park on the company's land.

Transformer Station, Etc.

On the tableland, immediately west of its works, the company has acquired a large tract of land, and on it has been built a transformer station of 25,000 h.p. capacity, 80 feet wide by 120 feet long, having a main central room 38 feet wide equipped with a 15 ton Whiting electric travelling crane, copper oil tank, suction pump and motor, and cast iron jack rails, resting on concrete foundations. On these rails there has been installed, for the present, 12 transformers of 15,000 K.W. total capacity, fully equipped with water cooling, drainage, and lead lined oil drainage systems. These transformers are for 40,000 or 60,000 volt transmission, and are separated from the low tension and high tension switchboards by solid brick curtain walls, the cables being brought to the transformers through passages underneath the concrete floors and carried from them through overhead arches in the curtain wall, thence to the high tension switches, from which the wires will pass out of the building through specially designed windows.

The building itself is of pressed brick, with stone sills and Ludowici tile roof, and is entirely fireproof, except window frames. It has a central monitor roof for light and offices near the front entrance, which is a door of capacity for fully loaded freight cars to enter far enough to transfer loads to the crane.

Adjacent to this station has been built a stand pipe 30 feet in diameter by 116 feet high, which is connected to the main water

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STANDPIPE FOUNDATION.

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system, from wheelpit to transformer station, and the flow of water from which is controlled by a motor driven valve operated from the transformer station, the object of which is that in case of fire the stand pipe can be cut out, and the two pumps at the wheelpit, by working tandem, can raise the pressure of water to 120 lbs at transformer station floor line during the fire period.

The function of this standpipe, however, is purely one of reserve in case of a breakage of the pumping and pipe systems supplying the transformers with water for cooling, in which event the standpipe capacity is estimated as being sufficient for 50,000 h.p. for 24 hours, or for 48 hours for the present station.

In view of the importance of continuity of operation this safeguard, although costly, was considered necessary; indeed, speaking of the equipment in general, every effort was made to design the plant so as to obtain a maximum of reserve in cases of breakdown.

Power House Machinery.

For handling materials two fifty-ton four motor electric travelling cranes were installed, which, by working with a carrier, can together handle practically 100 tons. These cranes operate with 125 Volt D.C. current, and have auxiliary five-ton hooks for fast service and light loads. The Sellers cranes, which are the ones here used, have as a distinctive feature, fixed drums, the carriage only travelling. The speed requirements with full loads were:—main hook, 10 ft. per min.; auxiliary hook, 50 ft. per min.; trolley travel 25 to 50 ft. per min.; and bridge travel 200 ft. per min.

The main turbines have twin draft tubes emerging into the sides of the pit immediately above the invert, and, owing to the great depth of water which there will be normally in the pit with the whole plant in operation, not to speak of the effect of back water during high water in the lower river, it was necessary to locate the turbines about 47 feet above the invert of the tunnel, and although air pressure is equivalent to about 33 feet water head, it has not been found practicable to operate safely with more than 25 feet of draft tube effect, which necessitated some artificial means of creating a pondage in the wheelpit with only a few wheels in operation.

This result was obtained by installing a huge regulating lift gate at the extreme lower end of wheelpit, where connection is made with the tunnel, and operating the same by lift screws, overhead girder, and 85 h.p. 125 Volt D.C. motor (a second motor in reserve). The water will pass under the gate, and in order to resist the constant vibration, very heavy cast iron grooves, grouted and bolted into the brick lining walls of the wheelpit, rest against

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masonry specially cut and built into these walls to receive the grooves, and the gate is equipped with an oiling system fed from a flexible piping.

The 10,000 h.p. turbines are described as twin inward discharge, Francis type, operating at 250 rev. per min. under 136 feet net effective head, and have solid bronze runners 5′ 0″ diam., and cylinder gates, controlled each by four racks and pinions. The racks move on opposite sides of the pinions, so that one gate rises as the mate to it lowers, the whole movement for each unit being controlled by a connecting rod from the Escher Wyss governor situated on the power house floor.

The revolving parts of a turbine and generator, and the shaft connecting them, are supported as follows:—In addition to the upward thrust on the lower runner, there is a balancing piston located immediately above the wheel case, and the piston for each unit is directly supplied with water from the forebay by a twelve inch pipe, but as a reserve, in case of accident, there is also a connection with each penstock.

In addition to this there is attached to each main shaft immediately beneath the generator a thrust bearing, capable, when operated with high pressure oil, of carrying the whole weight of the revolving parts of a unit, which amounts to about 243,000 lbs. This bearing is fed from the oil chamber with oil, which is raised to a high pressure by a pump located immediately alongside on the thrust deck; after leaving the bearing the oil flows back to the chamber to be cooled, clarified, and pumped back again to the thrust deck. The turbine shafts are hollow seamless cylinders 40 inches in diameter with weldless flanges, which connect by couplings to nickel steel bearing shafts 14 inches diam., bored out 8″, at the various bearings and connections, there being, as shown on Plate IX., two intermediate bearings for supporting the shaft between the thrust bearing and balancing piston.

The main penstocks each consist of a lower cast steel elbow in two sections, weighing 49 tons, which sits astride of the pit and carries the weight of the penstock and the water contained therein; above this are five straight sections of rivetted pipe ten feet two and a half inches in diameter, having weldless steel flanges, and an expansion joint connecting to the cast iron mouthpieces in wheelpit wall by a steel upper elbow. The calculated speed of the water with full load on a unit is about 11 feet per sec.

Five units of 7,500 K.W. output each, make the present installation, but the plant is built for eleven such machines, the eleventh being counted a spare, and in order to increase the present output it will only be necessary to extend the power house building and install such machinery as may be required.

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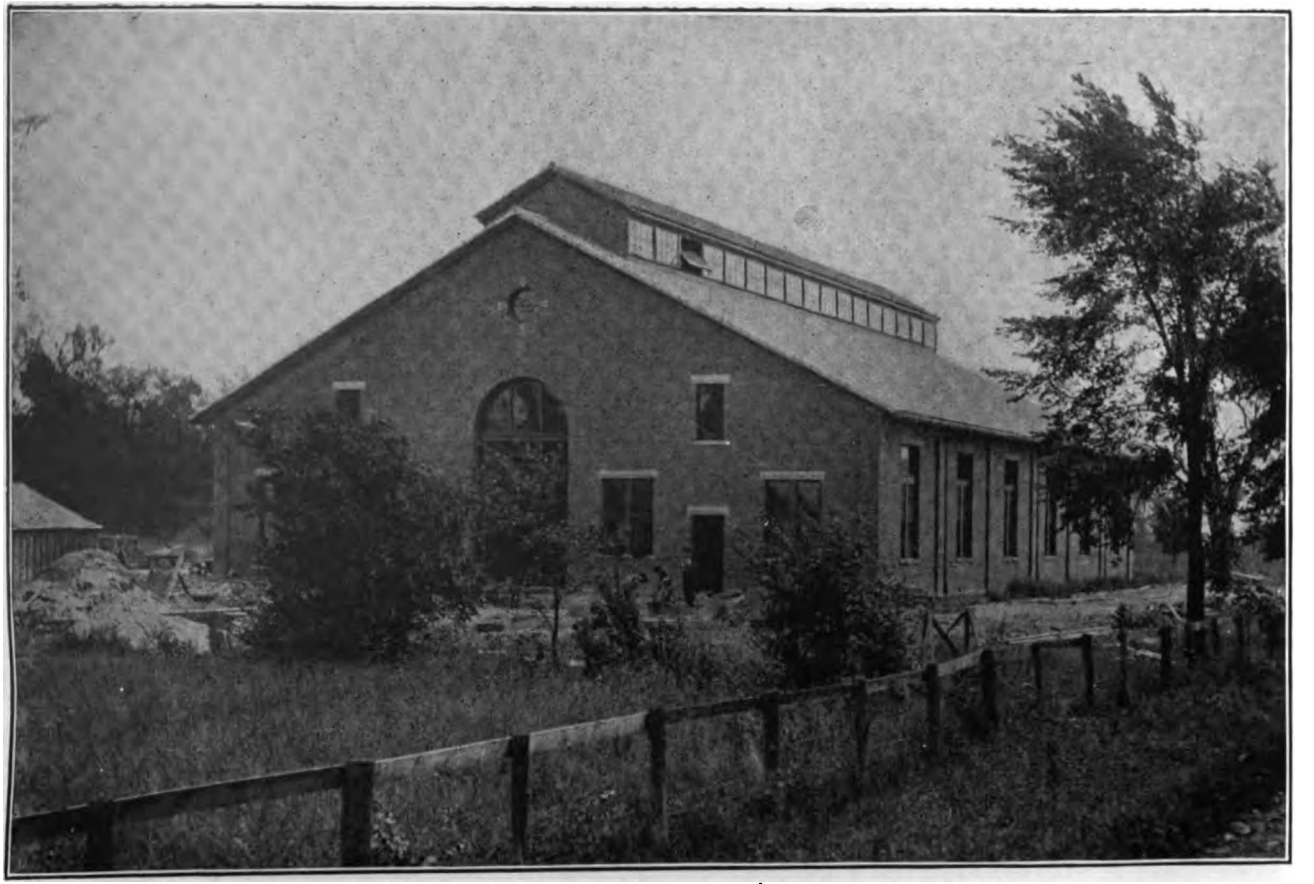

TRANSFORMER STATION.

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TRANSFORMER STATION.

TUNNEL PORTAL HEADWALL.

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For supplying the various water-driven machines in the chambers, an independent water system has been installed, which consists of a 36-inch rivetted main with weldless flanges, along the rack deck, fed from the canal by two 36-inch and five 24-inch vertical pipes. Of these, one 36-inch and two 24-inch pipes are in the first installation. From this main, which is sub-divided by valves at various points, rising pipes enter the chambers and, after operating the machines, the water passes by draft tubes into the tailrace below.

In one chamber is located an exciter plant, making 125 Volt D.C. current, which is used not only for excitation of large generators, but for operating cranes, switches, various gate and pump motors, and lights, etc. This plant consists of three vertical direct connected units of 332 h.p. each, the turbines being single, spiral case, inward and downward discharge, running at 600 rev. per min. under 131 ft. head, and controlled by Lombard governors. These units have oil bearings supplied with low pressure oil from the oil chamber, and are each quite independent, so that any unit can run with the other two shut down for repairs.

In a second chamber are located two pump units. Each unit consists of a horizontal turbine direct connected to a centrifugal pump of 3,000,000 galls. per 24 hours capacity. These pumps can, as before remarked, be run in tandem in case of fire so as to produce a fire pressure at the transformer station of 120 lbs., with a pressure at the pump of 210 lbs. per sq. inch. The turbines are driven from the 36" auxiliary main and discharge into the tailrace by draft tubes built into the brick wheelpit lining, while the pumps draw their water from one of the 24" supply pipes from the canal and discharge by a 24" pipe up the wheelpit, and thence out and to the transformer station, a half mile distant, by a 12" water main.

In a third chamber there is a very complicated system of motor and Pelton driven Quimby screw oil pumps, oil tanks, filter tanks, and cooling tanks, all so inter-connected as to produce necessary circulation, which consists, briefly, in there being two circuits, one for low pressure and one for high pressure oil. The oil traverses from a machine back to the cooling and filter tanks, thence to the suction tanks, from which it is again pumped back to the machine. The high pressure oil is handled in the same manner, except that a special pump is located at each thrust bearing, and raises the oil pressure at these bearings, after which this oil also flows back to the oil chamber to be cooled and clarified. In this chamber is also a specially designed Pelton driven air compressor, and in a chamber on the upper level adjacent to the main subway are located storage tanks of large capacity for storing oil, while a pressure oil tank is also located in the roof of the power house.

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The main power house floor will contain only three items of equipment, namely, the 7,500 K.W. generators, the turbine governors, and the main switchboard. So that the view from the visitors' gallery will be one of extreme simplicity, as the armatures of the generators are external and stationary, and the governors are very innocent looking machines in line with the generators, and not observable from the north end of the power house. The generators are about eighteen feet in diameter, with internal revolving fields, and deliver three phase 25 cycle current at 12,000 volts, which was adopted in order to enable local distribution for several miles to be made without transforming.

As these generators were both too large and too heavy for transportation it was necessary to have them completely assembled at the shops, then taken apart and packed in hundreds of boxes, and shipped knocked down to the works, where it took several months to re-build the fields and armatures piece by piece, there being, it is understood, 47,000 punchings in each armature.

Plate VII. shows two subways just below the power house floor, one to the right being for cables, and the main one to the left for cables and for the substructure of the main switchboard, which, for each 50,000 h.p., is about 150 feet long. The subway itself runs the full 600 feet length of the plant, and has a series of chambers opening off to the left, one at each inlet breast wall, which will be devoted to miscellaneous purposes, such as location for small transformers, etc. The main switchboard consists of a lower part in the subway, made up of bus-bar compartments, divided up vertically by brick walls and horizontally by soapstone slabs, and containing motor operated oil switches, and above the power house floor the switchboard proper from the gallery of which a full view of the power house is had, and which is equipped with switches necessary for full control of the station.

Cables leave the power house by three manholes, one situated at each end and one at the west side, from whence they pass through conduits, already described, either to the transformer station or to Niagara Falls N.Y., to deliver current supplementary to that generated by the Niagara Falls Power Company. These cables are lead covered, 2½" diameter, and contain three phase 19 strand copper conductors, each ½ inch diameter, which are insulated by paper and gum wrappings, the whole three being again insulated by similar wrappings beneath the lead covering.

The ground for this plant was broken in September, 1901, although the tunnel and cofferdam had been nominally commenced somewhat earlier, and water was turned into the forebay Nov. 9th, 1904, the exciter chamber was ready for operation Nov. 24th, 1904, and the 1st 10,000 H.P. unit December 23rd, 1904,—while two 10,-

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CONDUIT CONSTRUCTION.

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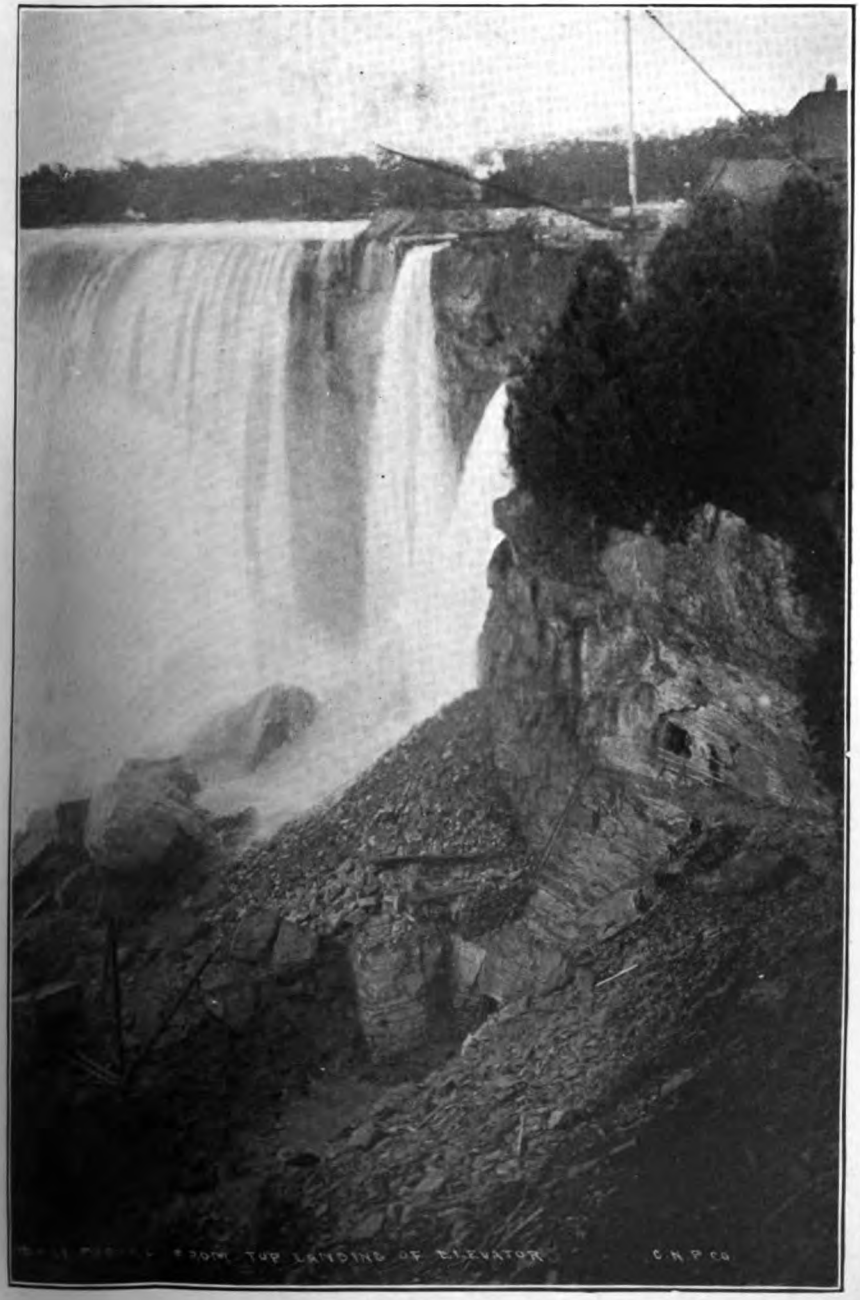

TUNNEL PORTAL EXCAVATION.

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000 h.p. units were ready for operation January 1st, 1905. The third unit will be put in operation in a few months, and the fourth and fifth units during the summer of 1905, while the extension of wheelpit complete, brick lined, and ready for the machinery of the remaining six units should be completed during 1905.

It will be appreciated that during this period Queen Victoria Park, with two other large and one smaller plant under construction, was in a state of great chaos, and this is largely the case at the present time, but the companies are under obligations to place their respective areas in good condition as soon as construction is finished, and when this has been done the southern part of the park, which was always in a state of nature, will be vastly improved. The Canadian Niagara Power Company, in process of construction, filled in the foreshore of the river for about 100 ft. in width from the Horseshoe Falls southward for over ½ mile, and this will be also sodded and added to the park area.

The principal contractors connected with the works were:—James Barry, cofferdam; Dawson & Riley, wheelpit and canal; Queenston Quarry Co., arch bridge; A. C. Douglas, tunnel and portal; Wm. Grace Co., power house; Brass Bros., transformer station; Escher, Wyss & Co., turbine units No. 1 2, 3; I. P. Morr's Co., turbine units No. 4, 5; General Electric Co., generators and main switch-board; Jenckes Machine Co., exciter turbines; Westinghouse Electric and Manufacturing Co., exciter generators; Canadian General Electric Co., transformers; Canada Foundry Co., various lift gates, etc.; Hamilton Bridge Co., power house steel work; in addition to which a great many contracts were placed in Canada and United States for various pipings, steel floors, smaller machinery, etc. The policy was at once established of having continuous and thorough inspection in keeping with the rigid specifications and high class of work demanded, and a large number of inspectors were employed, who were located at the various manufacturing centres and on the works itself. As these men were all the best that could be found for the various classes of work being done, it is believed that the results warrant the large attendant expenditure. For mill material, the Pittsburg testing laboratory did the inspection.

For the complete study, design, and execution of such an undertaking as has just been described, the engineering department was necessarily somewhat complex, there never having been any chief engineer, either nominal or actual, the organization being as follows:—Chief mechanical engineer, Dr. Colman Sellers; consulting hydraulic engineer until December 31st, 1903, Clemens Herschel; consulting engineer until March 1st, 1904, W. A. Brackenridge; resident engineer in charge of construction, Cecil B. Smith; Electrical engineer, H. W. Buck.

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Speaking generally, the designing was done under the direction of Consulting Engineer Brackenridge and by the designing staff of the Niagara Falls Power Company in charge of A. H. Van Cleve until March, 1904, since which time the writer assumed Mr. Brackenridge's functions, but the liberal policy of the company was, that all the main points of design were determined after full discussion by the various engineers mentioned.

In carrying on the work of construction the company allowed the writer full choice of whatever staff was considered necessary, and to employ also such inspectors in different branches as were needed. The chief assistants were as follows:—Principal assistant engineer, G. A. McCarthy; assistant mechanical engineer, C. C. Egbert; assistant electrical engineer, G. E. Brown; assistant engineer of wheelpit and canal, Wm. Macphail; assistant engineer of tunnel, L. Sherwood.

To these gentlemen the writer wishes to here tender his extreme appreciation of those qualities which made it possible to carry on such an extensive work with satisfactory results, and in that harmonious spirit which prevailed from the commencement of the work until the time (Dec., 1904), when the writer completed his engagement with the company.

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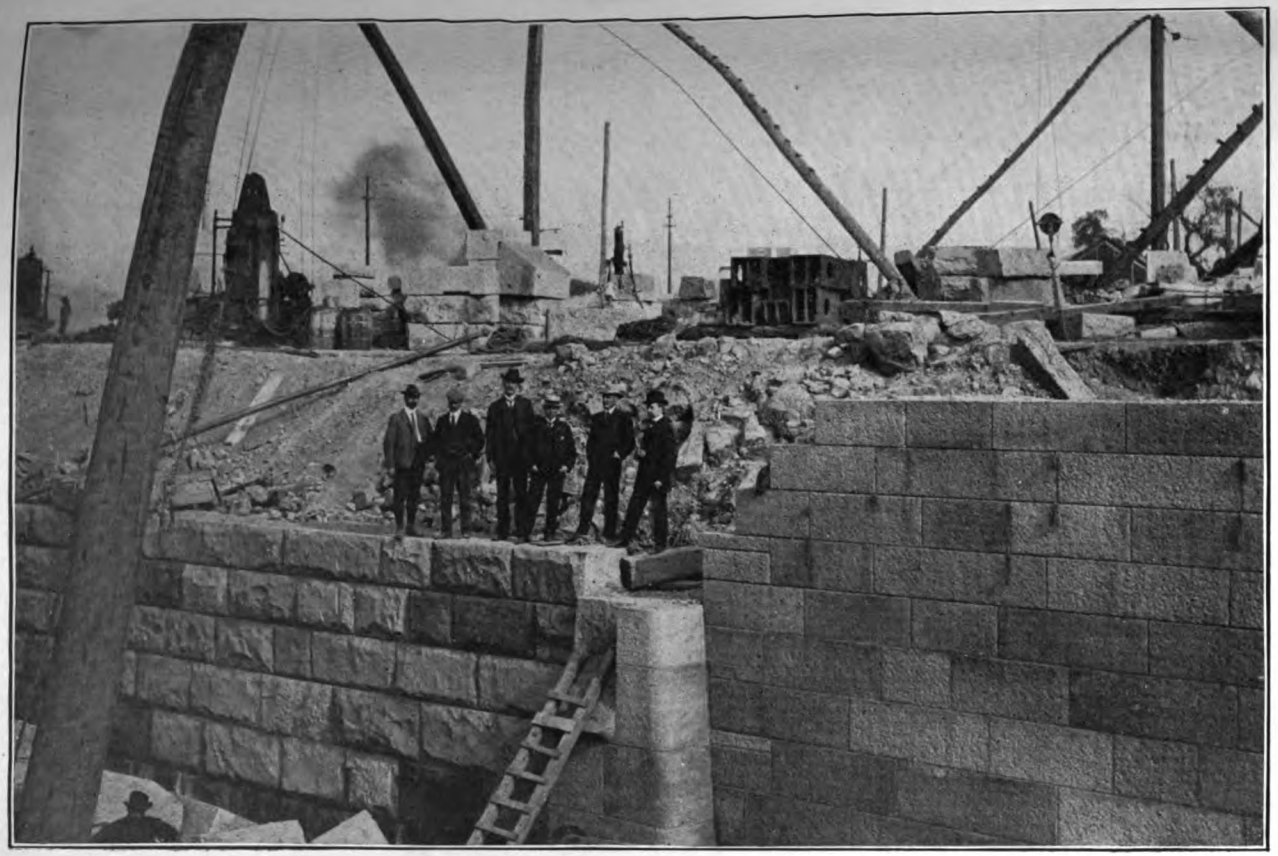

GROUP OF DIRECTORS, OFFICERS AND ENGINEERS.

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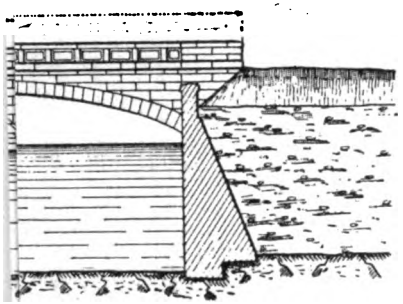

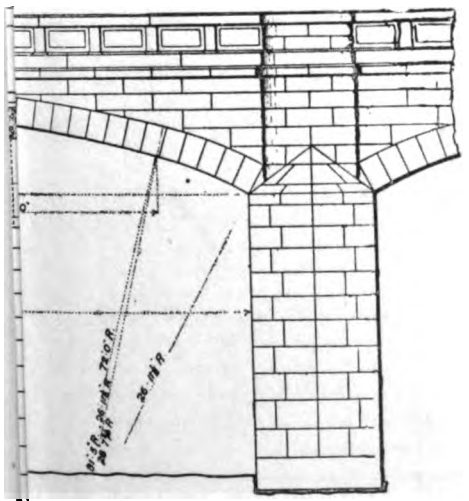

GARA POWER COMPANY

GE OVER CANAL INLET

1902

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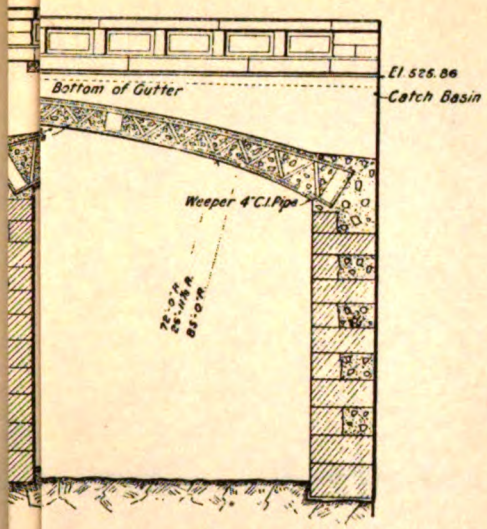

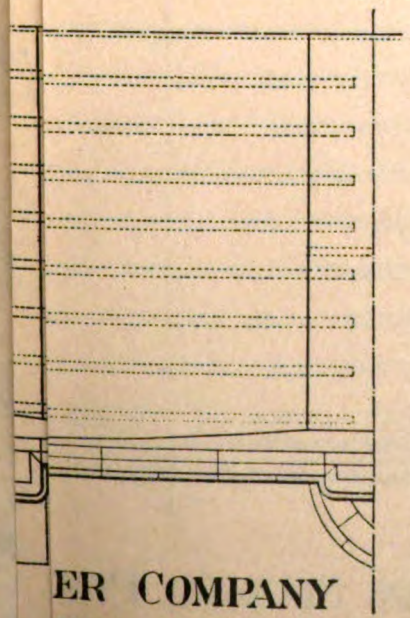

ER COMPANY

ANAL INLET

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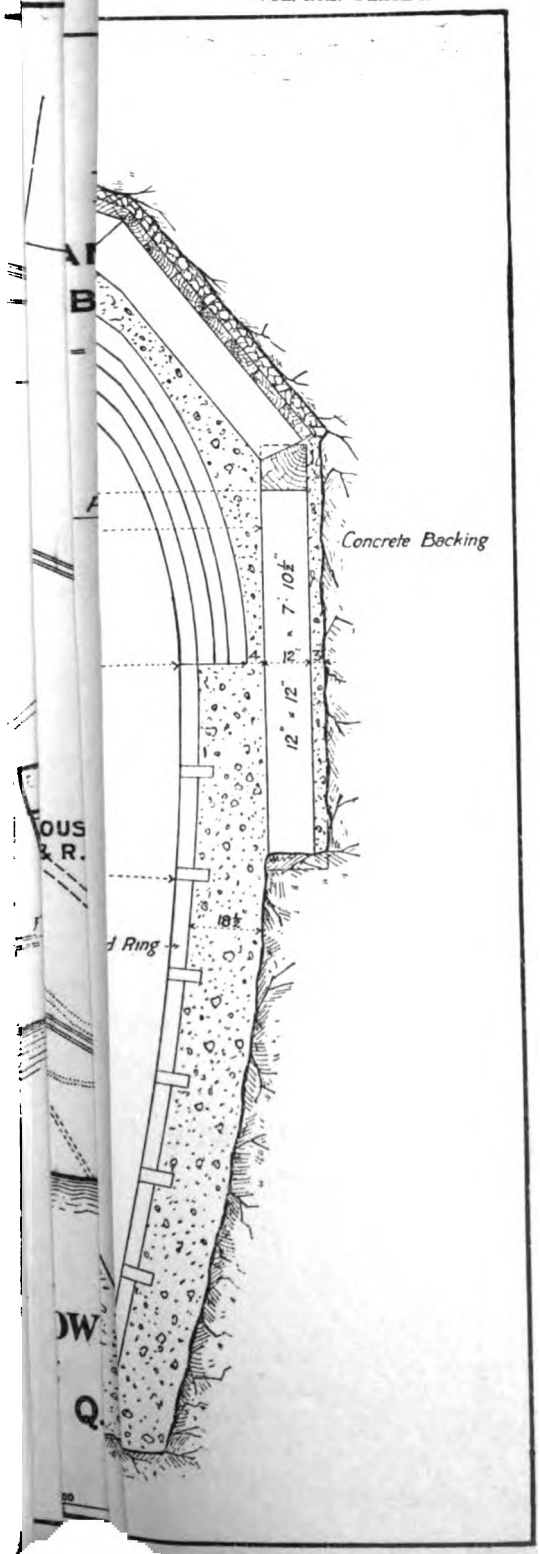

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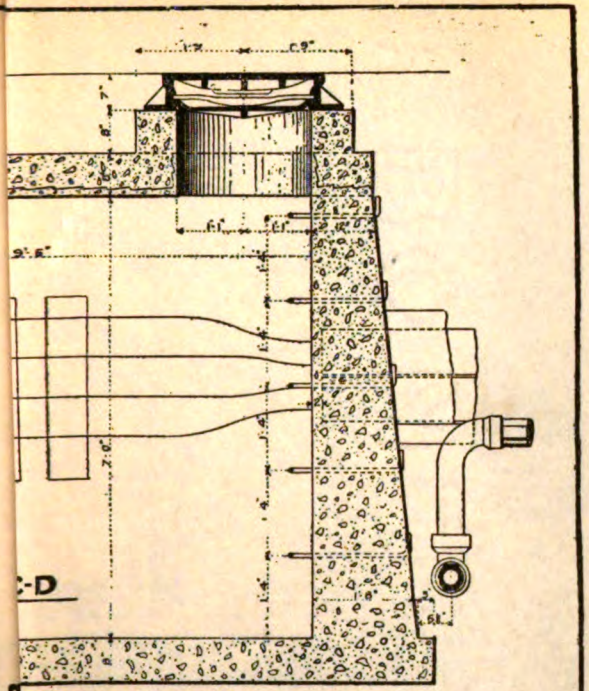
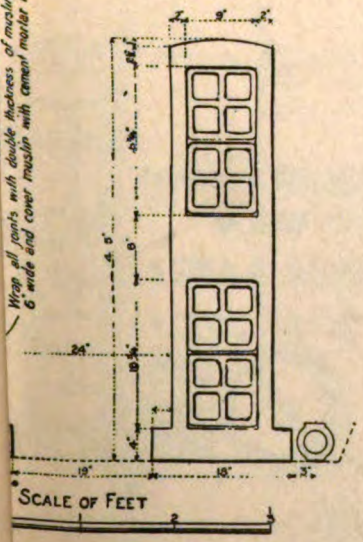


C-D

SECTION A-B

Wrap all joints with double thickness of muslin 6" wide and cover muslin with cement mortar 1:3



SCALE OF FEET

GARA POWER COMPANY

ROM POWER HOUSE TO

FORMER STATION

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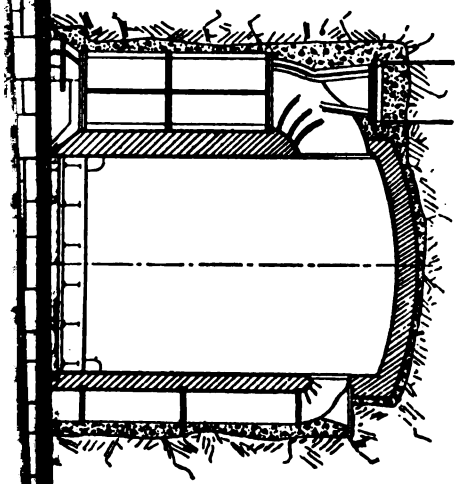

NY
EEL PIT

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CORRESPONDENCE.

Mr. C. P. Baillairgé, in discussing Mr. Smith's paper, wrote that on page 64, under the heading of "Canal and Forebay," Mr. Smith had written as follows:— Mr. Baillairgé.

"It will be noticed that these walls are of second-class rock-"faced coursed ashlar backed with 1:3:5 concrete.

"Plans were also prepared showing solid concrete walls below "low-water, but the use of concrete as a facing to be presented to "the wear of moving ice-laden water, although at a low velocity, "was not approved of by Consulting Engineer Herschel, and the "present plans were adopted instead at considerably increased "cost."

Col. Anderson, in his retiring address as President of the Canadian Society of Civil Engineers, in referring to concrete construction, said:—

"Concrete is now largely used in Canada to replace the more "expensive cutstone previously used in heavy foundations, and in "bridge abutments. Culverts have been built in concrete on the "Canada Atlantic and other railways, and illustrations will occur to "every member, of works in which concrete has been used with most "satisfactory results. This applies particularly to a country in "which masons or skilled laborers of any kind are scarce and ex-"pensive and the resultant quality of masonry questionable."

The piers of the Interprovincial bridge over the Ottawa between Hull and the Capital are also of concrete, below as well as above water.

Mr. Baillairgé continued that some years ago in a discussion as to the relative merits of stone and concrete for certain portions of the Harbour Works and Custom House landing piers and steps, he had expressed himself as fully of the opinion of Mr. Herschel, that with regard to angles of piers or their arrises, there was danger of erosion by swiftly moving ice-laden waters, though he had not gone so far as Mr. Herschel in including breast walls where the action of ice being merely attritional and not aggressive, is not subject to strike or exercise a thrust, as it might do against the angle of a pier, and could, therefore, have no disintegrating or destructive effect.

In reporting quite recently to the ecclesiastical authorities in Quebec, as to the opportunity of using concrete or artificial stone in the erection of churches, school-houses, etc., in situations where stone is scarce or costly of transportation, he had recommended the material where passenger traffic and ordinary vehicular traffic were not likely to wear away the angles or arrises of concrete con-

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Mr. Baillairgé. structions; leaving it to be inferred, of course, that where heavy vehicular traffic obtained, the quoins of buildings subject to be thrust against by heavy trucks and loads, might, as in the case of bridge piers, be endangered by erosion, disintegration and wearing away of the concrete to an extent rendering it advisable to use cut stone quoins at all such salient angles.

Under the circumstances, the opinion of Mr. Smith and others would be most interesting as to this pertinent question of the resistance of the salient angles or arrises of bridge piers and others to erosion by moving ice, so as to arrive at a safe conclusion in regard to land structures under analogous circumstances.

Mr. Smith. Mr. C. B. Smith, replying to Mr. C. P. Baillairgé's remarks, wished to say that the draft design for solid concrete walls for canal and forebay and other situations, was only for that portion extending from the foundations up to within two feet of low water level, while above that point rock-faced limestone was shown, partly to present a masonry face to the abuse of floating masses of ice, etc., and above water for the sake of appearance, it being felt that water moving not more than 2¼ feet per second with only frazil ice in suspension, would be quite harmless in eroding concrete. He was still of the opinion that constructing in above manner would have been good engineering, and indeed, leaving aside the question of appearance, that solid concrete walls under the same conditions would have been as durable as limestone, and much cheaper.

It must be understood that the work was all built in the dry, and had about a year in which to harden.

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PAPER No. 220.

MAPS AND MAP-MAKING IN CANADA.

By JAMES WHITE, Dominion Geographer.

In this brief paper nothing has been attempted beyond a sketch of the progress of the mapping of Canada from the beginning to the present time, with notes respecting what is now in hand, what it is proposed to undertake in the near future, and a list of some up-to-date maps issued by the Dominion and Provincial Governments.

A review of maps of Canada would not be complete without some notice of the first map containing the name "America"—though no portion of Canada is included in it—known as the Waldseemuller map of 1507. The only original copy that has been preserved is that recently discovered in the library of Prince Waldburg-Wolfegg, at Wolfegg, in Wurtemburg. Its preservation was, doubtless, due to the fact that its original owner, the cosmographer, Johann Schoner, had it bound in an atlas, whilst the others of the edition of 1,000 copies were probably mounted as wall maps and perished, owing to their enormous size. The original map is a surprisingly excellent example of the wood-cutter's art, and is the earliest known example of the production of a large wood-cut in so many plates—12 sheets. It has been reproduced by photo-lithography from the original with all the errors and without retouching. It is the irony of fate that Waldseemuller, though one of the foremost geographers of his time, is better known in consequence of his error—an error that he corrected in his 1516 chart—than of his extensive and important cartographic work.

One of the first maps that showed any considerable portion of our Atlantic coast, was drawn in colour on oxhide, in the year 1500 by the pilot Juan de la Cosa. It has been a sort of geographical storm centre round which the Cabot controversy has raged, the advocates of each theory finding proof of its accuracy therein, even if the proving requires the abstraction of a portion and its revolution through 90 degrees.

Up to the close of the sixteenth century Canada (or New France) was not usually mapped, except as a portion of America or the Western hemisphere. Subsequent to about 1590 its increasing importance, and the fact that it constituted the possessions of France in the northern portion of the continent, justified separate maps, the best of which were, for many years, published in Paris

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and Amsterdam. The most notable makers of maps of Canada during the seventeenth century were, on the Continent, Sansan, Jaillot, de l'Isle, Berlin and d'Anville, and, in Great Britain, Bowen, Jefferys, Kitchin and Mitchell. The last named is of special interest to Canadians, as it is due to the errors in a copy of his map of 1757 —which was used during the negotiations preceding the treaty of Versailles—that the International boundary follows the Pigeon and Rainy rivers to the Lake of the Woods instead of ascending the St. Louis river from what is now Duluth.

In 1795, Aaron Arrowsmith published the first of the series of maps of Canada that have indissolubly connected his name with the mapping of this country. All the surveys made, and all the geographical information collected by employees of the Hudson Bay Co. were placed at Arrowsmith's disposal and incorporated in his maps; thus we have new editions of his 1795 map in 1811, 1818, 1819, 1820 and 1821. This connection gave him a unique and—so far as Canadian geography was concerned—a very advantageous position till the absorption of the North West Co. by the Hudson Bay Co. in 1821, gave the latter a monopoly, and the retrenchment necessary to repair the losses due to the ruinous competition prior to the union resulted in an almost complete cessation of surveys.

During the early part of the nineteenth century, the strenuous competition between the Hudson's Bay, "X Y," North West and other fur-trading companies stimulated explorations in our northern and western territories to an unusual degree—not the least of the results of which was the crossing of the continent in 1793, by Alexander Mackenzie, which secured to Canada what is now the Province of British Columbia and also, consequently, a Pacific coast-line. To make the surveys and map the explorations, these companies employed several very able men, notably the famous David Thompson, later one of the Commissioners appointed to delimitate the International boundary between Cornwall and the north-west angle of the Lake of the Woods—and the comparatively unknown, but almost equally able Peter Fidler. It is noteworthy that the MSS. maps of these geographers are still unpublished, though the information has been incorporated in other and later maps and, even at the present time, the surveys of Thompson and Fidler constitute the best information obtainable with reference to some portions of our North West. Thompson's map is in the Crown Lands Department, Toronto, and Fidler's is the property of the writer, who hopes that the Government will some day authorize their publication and thus perpetuate their great works.

In 1815, Joseph Bouchette, Sr., published a map of British North America, and in 1831, his son, Joseph Bouchette, Jr., prepared a map of the British North American provinces on a scale of about 14 miles to 1 inch.

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In 1844, a geological survey of Canada, under the direction of Mr. (afterward Sir) William E. Logan, was commenced. Sir William found the surveys and maps so defective that he and his assistants were forced to devote a great deal of their time and attention to topographical work, and he has aptly summarised the difficulties with which he had to contend as follows:—

"Many of the difficulties encountered in making a geological survey of Canada have arisen from the want of proper topographical maps, and also from the fact that great parts of the country were wholly unexplored, and consequently not represented on any map. In older countries the labors of topographers and geographers have preceded those of the geologist, and have given correct representations of the surface, rendering the subsequent geological investigation comparatively easy. But in Canada the want of such maps has compelled the geologist, in many parts of the country, to study its topography as a preliminary to the representation of its geology. Hence a great part of the labours of the Survey during the last twenty years has been bestowed upon topographical researches, the extent and importance of which will appear from the summary to be given farther on. These additional labours, and the unwelcome task of map-making imposed upon the officers of the Survey, have been the source of great delays in the geological investigations."

In 1866, he published the large geological map of Canada which, with the "Geology of Canada," 1863, will always remain an enduring monument to Canada's first geologist. Since 1866 the Geological Survey has made surveys in all portions of the Dominion, and has issued about 250 sheets of various sizes and scales, many of which, of course, overlap each other.

Since its very inception, nearly all the maps published by the Geological Survey have included a large amount of topographical information based on surveys made by its own officers—not that the work was undertaken from choice, but because they were forced to make them to supply deficiencies and to correct errors in the existing surveys. The attitude of the Survey has been, consistently, one of protest, as this work has absorbed funds that were required for geological work while, at the same time, the publication of the report of the geologist has frequently been delayed, pending the completion of the surveys and, consequently, of the map. While the Survey has thus issued many valuable maps, still as they were only a means to an end, that is, as they were prepared only for regions that were of geological interest, and in which geological investigations had been undertaken—many districts that, from a purely geographical and economic point of view are of great importance, have, perforce, been neglected. Similarly, no up-to-date geological map of Canada has been issued since 1866, the one pre-

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pared in 1882 being based on a topographically defective map that had been compiled for another purpose.

Recognizing these defects in mapping as carried on in Canada the Hon Mr. Sifton, in 1899, appointed the writer to the position of Dominion Geographer, with instructions to commence the compilation of a new map of Canada, in 8 sheets and on a scale of 35 miles to 1 inch. As soon as it was completed the Standard Topographical map of the southern portion of the Dominion on a scale of $\frac{1}{500,000}$ (7.89 miles to 1 inch) was commenced, and sheets covering portions of New Brunswick, Quebec, western Ontario and southern British Columbia are now under way, attention being devoted first to the areas that have been wholly or partially neglected by other organizations. The thickly settled portions of the eastern provinces are also being mapped on a larger scale, viz., $\frac{1}{250\,000}$ (3.95 miles to 1 inch), which permits the inclusion of all the detail ordinarily required. When complete, it will be possible to supply applicants with sheets that are up-to-date and covering any required portion of the country. These maps are engraved on copper, and can thus be corrected from time to time by "beating up" the plates from the back. Each sheet includes a definite number of degrees of latitude and longitude—3 degrees in the $\frac{1}{500\,000}$ sheets and 1½ in the $\frac{1}{250,000}$ and any number of sheets can be joined together to form a map of any desired area. In addition, it is proposed to undertake work along other lines that will show forth the economic resources —developed and potential—of our country.

The following is a list of the principal areas in Canada that have been, thus far, mapped in detail:—

1-mile scale.—Cape Breton Island, Antigonish, Guysborough and Pictou, and portions of Cumberland, Colchester and Halifax counties, Nova Scotia.

2-miles scale.—Lake of the Woods, Rocky Mountains in the vicinity of the Canadian Pacific Railway, and small area near Dawson.

3-miles scale.—Sectional sheets on this scale, and including about 4,300 square miles each, of Manitoba and the Territories, south of approximate latitude 53° have been published by the Department of the Interior.

4-miles and 3.95 miles.—New Brunswick, greater portion of Prince Edward Island, Gaspe peninsula, southern Quebec from Ottawa to Quebec city, vicinity of Timiskaming, Nipissing, Sudbury, Haliburton, Perth, Windsor, London and Niagara Falls, Ontario

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and a large part of the same province west of Port Arthur, also contoured sheets including an area of about 20,000 square miles in southern British Columbia, the Atlin district and the valleys of Stewart and Macmillan rivers in Yukon, have been mapped by the Interior and Geological Survey. The Quebec Government has published maps covering the portion of the province lying between a line drawn from Temiskaming to Lake St. John and the St. Lawrence, also of the portion south of the St. Lawrence and east of Quebec. The Ontario Government has issued a 4-mile map of the surveyed portion of Nipissing district, and a 5-mile map of the country between Georgian Bay and the Ottawa.

6-miles scale.—A reconnaissance map of the Rockies between the Canadian Pacific and the International boundary, and a number of sheets including a large portion of southern Yukon have been published. Sufficient surveys to bring the information up to the 6-mile standard were not, however, available for these sheets, and they should be classed as 8-mile maps.

8-miles scale.—The greater portion of northern Manitoba, western Assiniboia and of Alberta, also central and southern British Columbia and part of eastern Saskatchewan, have been mapped on this scale. Elsewhere in northern Canada, many sheets usually showing some of the larger rivers and lakes and country in the immediate vicinity, have been issued, but, while very useful, they cannot be considered as containing the amount of information necessary to make a complete map for this scale.

12½-miles scale.—The whole of Manitoba, Assiniboia, Saskatchewan, and Alberta and western Athabaska has been mapped on this scale by the Department of the Interior.

Following this brief resumé of published maps, it will be in order to consider what is now in hand in the office of the writer, and what is proposed for the near future.

1st. The Standard Topographical map on a scale of $\frac{1}{500\,000}$ (7.89 miles to 1 inch), and the detailed sheets on the $\frac{1}{250\,000}$ scale (already referred to) are under way, and will be pushed to completion as fast as possible.

2nd. An Economic Atlas of Canada is well advanced toward completion, and will be issued during the current year. It will contain maps showing:—

(a) Territorial divisions of Canada.
(b) Relief map.
(c) Geology.
(d) Minerals.
(e) Forest resources and northern limits of trees.

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(f) Telegraphs and cables.
(g) Telephones.
(h) Railways—with the territory tributary to the various systems indicated by colors.
(i) Transcontinental railways.
(j) Canals, and sailing routes and distances between the inland ports on the St. Lawrence and great lakes.
(k) Bathymetric maps of the Atlantic and Pacific coasts, also showing lighthouses, sailing distances and routes between Canadian and foreign ports.
(l) Isotherms for months and year.
(m) Isobars for seasons and year.
(n) Rainfall and snowfall.
(o) Electrical divisions and counties.
(p) Density of population.
(q) Disputed International and Interprovincial boundaries.
(r) Routes of early explorers.
(s) Drainage basins, areas and lengths of streams.
(t) Distribution of Indian tribes.
(u) Cities with population of over 25,000.
Or about 45 maps in all.

In addition there are about 50 sheets of statistical diagrams of area, population, agriculture, finance, railways, manufactures, etc., largely based on census and customs statistics. Later, a hand-book, to accompany the Atlas, and containing a large amount of statistical information that cannot conveniently be included in the diagrams, may be prepared.

3rd. It is proposed to prepare gazetteers of the various provinces. They will include maps showing the geology and principal industries, notes re resources, etc. The letter press will contain descriptions of the foregoing and also a list, alphabetically arranged, of the cities, towns, villages, lakes, rivers, mountains, etc., with notes respecting the population, industries, etc., of the municipalities and respecting the area, altitude, length, etc., of the topographical features.

4th. A "Resource" map of Canada is now in the press. It will be on much the same lines as the "Industrial" map of the United States.

The writer, at first, proposed to add a list of the best maps thus far published, at the same time indicating in a general way the area included in the various sheets. As this would have necessitated the inclusion of some maps published by private enterprise,

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and, as it is desirable to avoid any distinctions that might appear invidious, the list has been omitted. However, any person desiring information connected directly or indirectly, with the geography or resources of Canada, is requested to apply to the writer and, if possible, the information will be given or, if not within the purview of his work, it will be referred to the proper department.

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PAPER No. 221.

THE EFFECT OF LOAD FACTOR ON COST OF POWER.

By E. M. ARCHIBALD, B.Sc.

The great desideratum for an electrical system is a high load factor with consequent greatest return on investment; load factor being the ratio of average to maximum load. All the factors of expense included in cost of power to the consumer are then operating at maximum economy, and cost of power is at a minimum.

The lighting of residences and offices produces a peak in the late afternoon and evening, with but little load the remainder of the twenty-four hours; consequently the average load on the plant with lighting only is very small and the load factor low. A commercial motor load in connection with lighting will increase the average load even though causing a greater peak. The addition of a street railway load still further increases the day load, but in consequence of the heavy demand load during the rush hours, when the public is going to and from business, which occurs at the peak of the lighting load, the peak load on the plant is greatly increased. This heavy peak, with but a small average load over the twenty-four hours, produces a low load factor, and a portion of the machinery being shut down the greater part of the time, higher rates must be paid by the consumer to secure a certain return on first investment than when the load factor is higher.

Evidently, when the load factor is 100%, that is when the load is constant throughout the twenty-four hours, and all the machinery is in continuous operation, the cost of power per K.W.Hr. is a minimum, and the greatest return on investment is realized. Customers having a steady load or with high average load are greatly desired and may be offered much better rates than all others. It will be the endeavour of this paper to determine the decreased cost of power with increasing load factor.

The storage battery is evidently a means in the hands of the power producing company of increasing the average load on the machinery. By charging the battery during light load and discharging during periods of heavy load, a more constant load on the generating apparatus is produced, with consequent better efficiency, and at the same time acting as a reserve in case of accident in the power plant. Unfortunately the battery is expensive, and a loss occurs in its operation which greatly reduces the higher efficiency

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secured by the increased load factor. The great benefits obtained by its use are reserve capacity and voltage regulation, enabling the use of more efficient lamps.

The storage battery, however, has not been considered in what follows, even where it might be desirable, but rather a plant is assumed of certain maximum capacity for the peak load, and we are to determine what effect various load factors have on the cost of power produced.

The various expenses involved in the cost of power to the consumer are as follows: (1) management; (2) distribution; (3) production.

For a given system with given peak load the cost of management is practically constant, no matter what the load factor.

The cost of distribution is constant with various load factors in so far as the fixed charges and maintenance is concerned. The losses in distribution, however, vary, these consisting of losses in lines, transformers if alternating current is used, meters, losses in grounds and losses from theft of current; all decrease the output and accordingly increase the cost to the consumer. While it is possible to determine fairly accurately the losses in lines, transformers and meters with varying load factors, the losses from grounds and theft are indeterminate and require constant attention to keep them within certain limits. Yet as a rule these latter will become a smaller percentage of the total output the higher the load factor.

There yet remains for consideration the effect of the load factor on the actual cost of production of energy.

The higher the load factor, the greater is the amount of power produced, the longer does the apparatus operate most efficiently, the lower the ratio of fixed charges to total operating expenses and consequently the lower the cost of power per unit.

To determine exactly in what proportion the cost of power is decreased, it will be necessary to assume a plant, determine the fixed and variable charges and thereby the cost per K.W.Hr. at various load factors.

Let us take for example a plant with a peak load of 750 K.W. Allow three units of 300 K.W. capacity each, so that in case of a break down to one, the other two may take care of the peak with an overload of 25% on each and sufficient boiler capacity for the same contingency. No provision is allowed for stokers, coal handling apparatus or economizers. Plant assumed to be on the water front providing sufficient water for condensing purposes.

Curves are also plotted for a second plant of the same capacity as the first, but operating non-condensing. In both cases either water or railroad connections assumed with convenient facilities for coal handling and removal of ashes.

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First cost of plant complete:—

Condensing, $118,425.00 equivalent to $131.60 per K.W.
Non-condensing, $114,625.00 equivalent to $127.40 per K.W.

Fixed charges.	Condensing.	Non-Condensing.
Interest at 5%..	$5,921.25	$5,731.25
Taxes and insurance at 2%..	2,368.50	2,292.50
Depreciation machinery 10%.	7,710.00	7,305.00
Building 3%..	1,122.00	1,134.00
Total..	$17,121.75	$16,462.75

The above first cost being for 100% load factor, there will be a varying reduction due to the decreased boiler capacity required on lower load factors. A point is reached below which it is not advisable to further decrease the boiler capacity as the peak load must be taken care of and sufficient reserve provided for accidents and repairs; this point being taken in this case at 40% load factor. The effect of this reduction is to diminish the fixed charges at 40% load factor by $1,000.00 per year, or about 6% of the total. From these figures the lower line in figs. 1 and 2 are plotted and indicate the effect of fixed charges on the cost of power.

The remaining items of expense are what are generally termed operating charges and are variable with load factor. These consist of (1) labor, oil and waste, supplies, water and repairs; (2) fuel.

The cost of labor varies to a certain extent with load factor, but a minimum number of men required to operate the plant is reached at about 40% load factor, below which this item remains constant. The cost of oil and waste, supplies, water and repairs varies almost directly with load factor as the greater number of hours per day that the machinery remains in service, the greater do these expenses become, and vice versa. The second line in figs. 1 and 2 is for these charges reduced to the K.W.Hr. basis and is added to the fixed charges curve; the difference between the two curves therefore represents the cost of labor, oil and waste, supplies, water and repairs.

The cost of fuel, usually coal, per unit of power generated, varies with some power of the load factor less than one depending upon the number and efficiency of units employed both in the engine and boiler rooms, also upon the cost per ton of coal, its heating value, and upon the ability of the firemen to get the best results; it is of the utmost importance to watch this item carefully, as greater economy can be secured in the cost of coal per K.W.Hr. than in any other item of expense. The calorific value of the coal should be tested from time to time and compared with the number of lbs. used per K.W.Hr.

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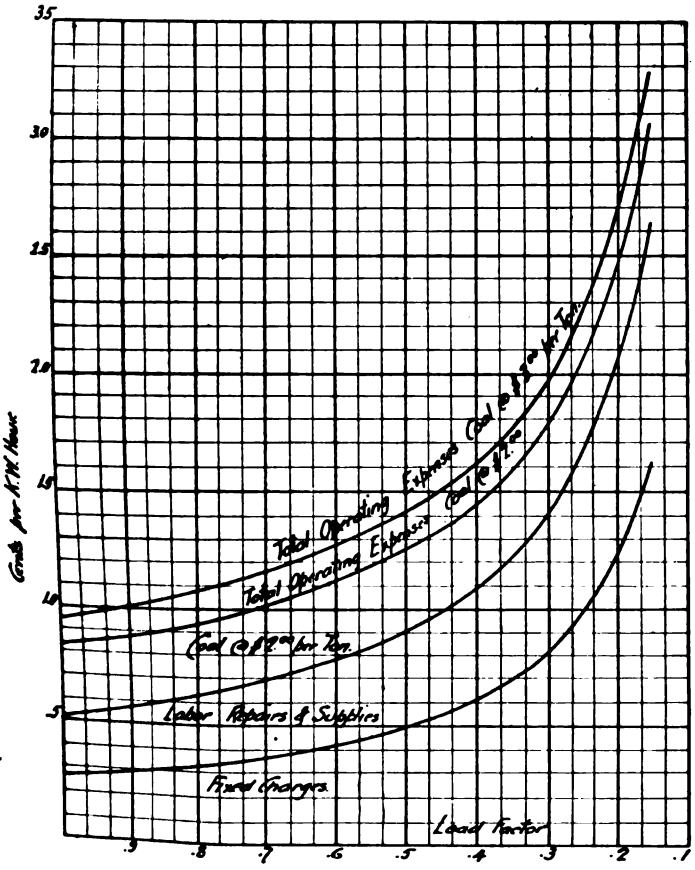
The coal considered is assumed to contain 12,000 B.T.U.'s per lb., and two curves are plotted in figures 1 and 2 when the cost is $2.00 and $3.00 per ton respectively, the results being added to the



Operating Expenses of 900 K.W. Condensing Steam Plant - Peak 750 K.W.

Fig. 1

two previous curves plotted. These figures of fuel cost per K.W.Hr. are above the average usually obtained and can only be secured by constant attention in the boiler room; for instance 45% load fac-

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tor in the first case 1 K.W.Hr. is generated from 3.5 lbs. of coal from the pile.

The ratio of the individual items of expense to total operating expense is shown by figs. 3 and 4 for the condensing and non-con-

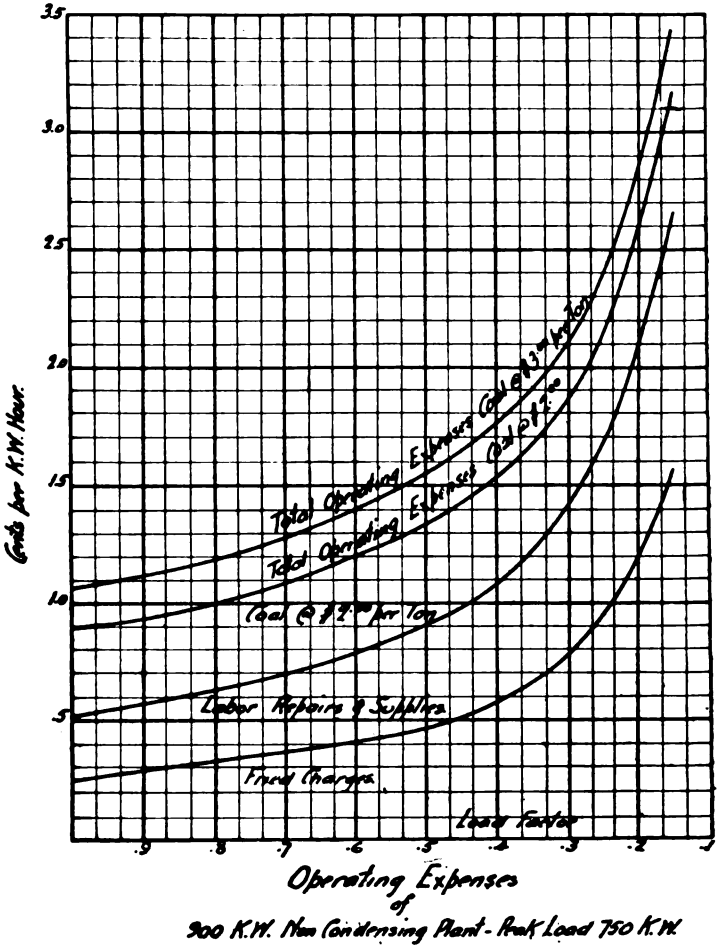

Fig - 1

densing plants respectively with coal at $3.00 per ton delivered. It is interesting in this connection to note the high percentage of fuel cost; in the average plant this percentage will be still higher than that shown, but this indicates how great a factor is the cost of fuel

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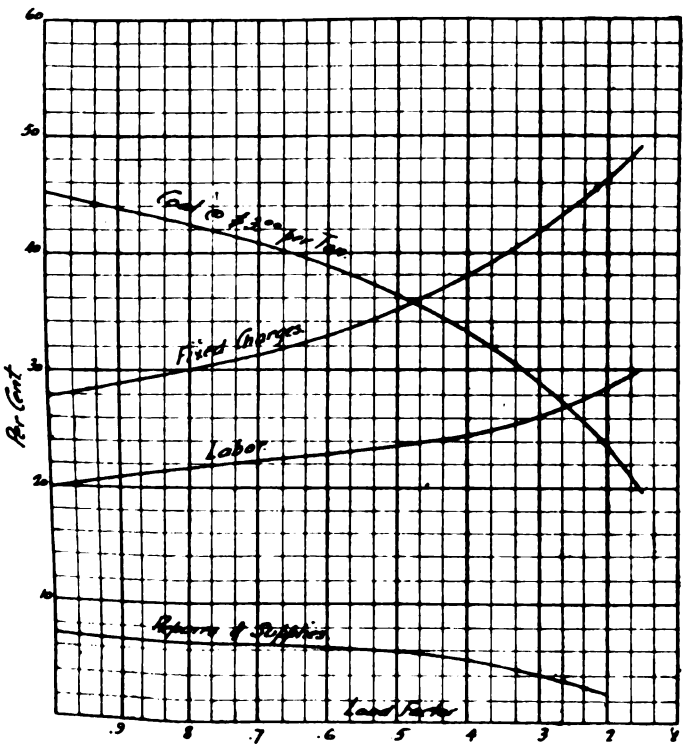
particularly with high load factors. For low load factor the fuel is subordinated by the fixed charges, which is by far the heaviest item.

Having thus determined the cost of power for a plant with a peak of 750 K.W., we shall consider briefly a larger plant and ascertain what extra economies may be secured. This plant we shall assume to have a peak load of 1,500 K.W. and a maximum capacity



Ratio of Individual Items of Operating Expenses to Total Operating Expenses
300 K.W. Condensing Steam Plant - Rate 750 K.W.

Fig 3

of 1,800 K.W., divided into three units of 600 K.W. each. Stokers are used, but no economizers or coal handling apparatus; the boilers are in a single line parallel to the engine room, and coal is dumped from the car into a chute, whence it falls to the floor of the boiler room.

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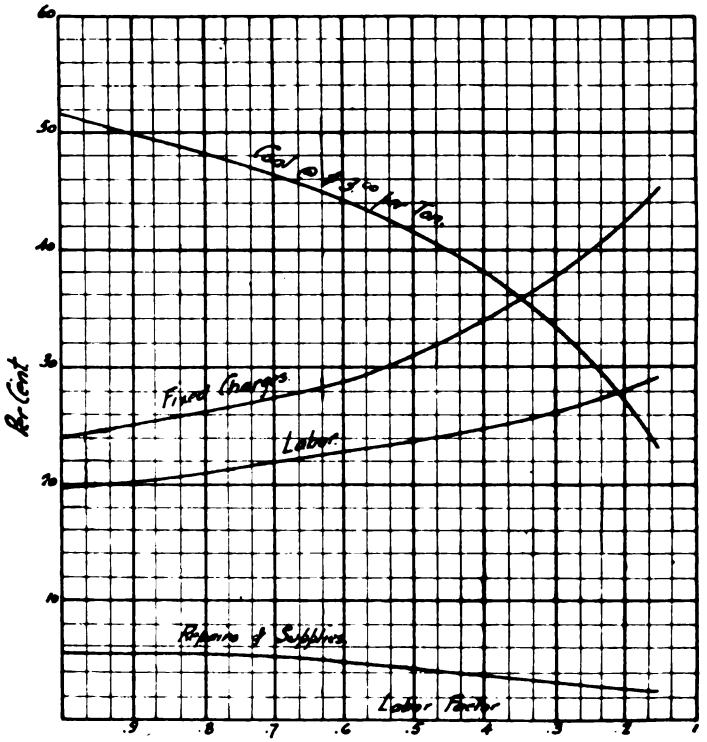
First cost of this plant at 100% load factor is $241,125.00, equivalent to $134.00 per K.W. Fixed charges, using the same per cent. for interest, depreciation, taxes and insurance as in the previous case become $36,318.75 per year. Curves are plotted in fig. 5 for fixed charges, labor, supplies and repairs, and fuel, the latter being plotted for the two prices $2.00 and $3.00 per ton as before.



Ratio of Individual Items of Operating Expenses to Total Operating Expenses.
300 K.W. Non-Condensing Steam Plant - Rated 300 K.W.

Fig. 4

With all these curves before us it might be well to make some deductions as to the advisability of further expenditures in the power plant in coal handling apparatus and economizers, or in general, any apparatus that tends to increase the economy.

The higher the load factor the greater becomes the ratio of

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variable to fixed charges, and extra investment is advisable to secure the greatest economy possible. Extra investment in coal handling apparatus and economizers will reduce the cost of labor and fuel in greater proportion than fixed charges are increased; the economizers also provides greater boiler capacity and purer feed water, reducing cost of repairs.

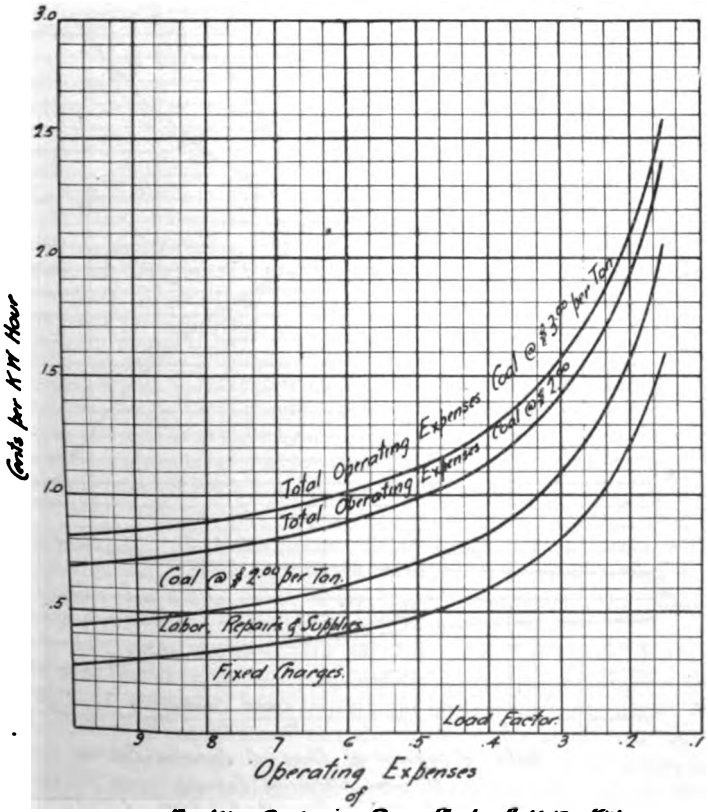

Fig. 5

On the contrary when the load factor on a system is low, the fixed charges are the governing factor in the cost of power, and extra expenditures must be carefully considered, particularly so if fuel is cheap.

Having thus discussed the effect of load factor on the cost of producing power, we shall next turn to the cost of management and

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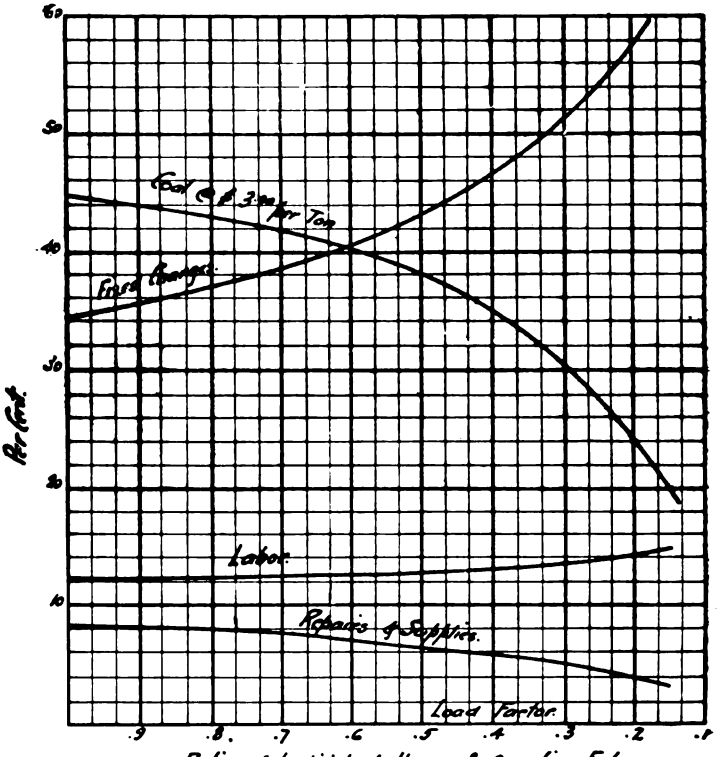
distribution. While it is beyond the scope of this paper to fully consider these costs, yet it was thought advisable to indicate by a curve including all the various costs approximately, how the load factor influences the cost to the consumer. This is done very generally, as no two cases are alike; the cost of distribution is more



Ratio of Individual Items of Operating Expense to Total Operating Expense.
1800 K.W. Condensing Steam Plant - Peak Load 1500 K.W.

Fig-6

variable with different systems than is the cost of power, depending on the conditions of distribution, conduit or pole line construction and the extent and density of the territory to be covered.

We shall allow that $50,000.00 per year covers all fixed charges, maintenance and attendance on the distributing net work; $35,000.-00 per year for management, dividends on stock and miscellaneous

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expenses. For total losses 30% of the output is allowed; this is taken constant for all load factors, for while the percentage of known losses varies directly with load factor, the percentage of indeterminate losses by grounds and theft varies inversely as the load factor. The actual losses from grounds are constant, hence percentage loss by grounds varies inversely as load factor; losses from theft usually occur with customers having a short hour load, and the greater the amount of such load connected, the greater this loss. A customer having a long hour load runs a greater chance of detection than others. Hence, the above statement holds that the total percentage loss will be constant. Further, this lost power reduces the amount of sales, therefore affecting all the expenses included in cost to customer.

Fig. 7 shows a series of curves plotted for the 1,800 K.W. steam plant, the lower line representing cost of production, the second, cost of distribution; third, cost of management, and fourth the effect of distribution losses on cost of power, this last being the final cost to consumer.

Coal is expensive, and from the nature of things will increase in price, and it behooves us to investigate any methods of producing power which is more economical in the use of fuel than the steam engine, and naturally turning to the gas engine we will next proceed to make a comparison between a steam plant and a gas plant generating producer gas for use in gas engines, and from such comparison deduce some general results.

As is well-known the gas engine has a very much higher thermal efficiency than the steam engine, which fact, together with the fewer number of auxiliaries required, would naturally lead one to suppose that a greater economy could be secured in the production of power.

Difficulties, however, are encountered at the outset in the kind of fuel that may be used successfully in the gas producer. While the gas generated from anthracite coal is very successful in the operation of gas engines, the gas from bituminous coal contains tar which, when carried through the valves into the cylinders of the engine, clogs the valves and carbonises under the intense heat to which it is subjected in the cylinder, preventing successful operation. Some manufacturers claim to have succeeded in removing the tar or preventing its formation, but the burden of proof still rests with them.

The overload rating of the gas engine is different from the steam engine in the ratio of about 15 to 50 per cent. Hence in designing two plants, steam and gas, for equal overload capacities, it is necessary either to use gas engines of 25 to 35 per cent. higher normal rating, with consequent poorer economy at normal load; or

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add an extra engine and generator sufficient to take care of the extra overload capacity of the steam engine over the gas engine. For example, in designing a gas plant of 900 K.W. capacity with a peak load of 750 K.W., allowing the same reserve as in the steam

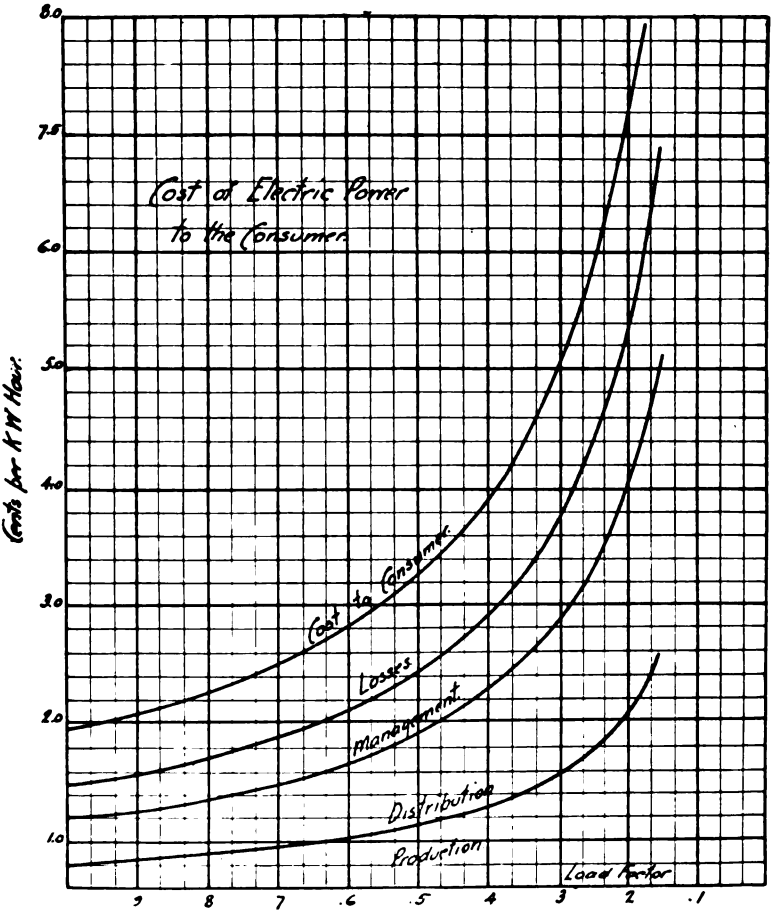

Fig. 7

plant considered previously, three engines of 530 B.H.P. each will be required with an aggregate normal B.H.P. of 1,590 and maximum B.H.P. of 1,830, as compared with three 450 I.H.P. equivalent to 410 B.H.P. engines aggregating 1,230 normal B.H.P. and 1,840 maximum

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B.H.P.; or three gas engines of 410 B.H.P. each and an additional engine of 360 B.H.P. aggregating 1,830 B.H.P. on maximum load (from a practical standpoint, this additional engine would be made

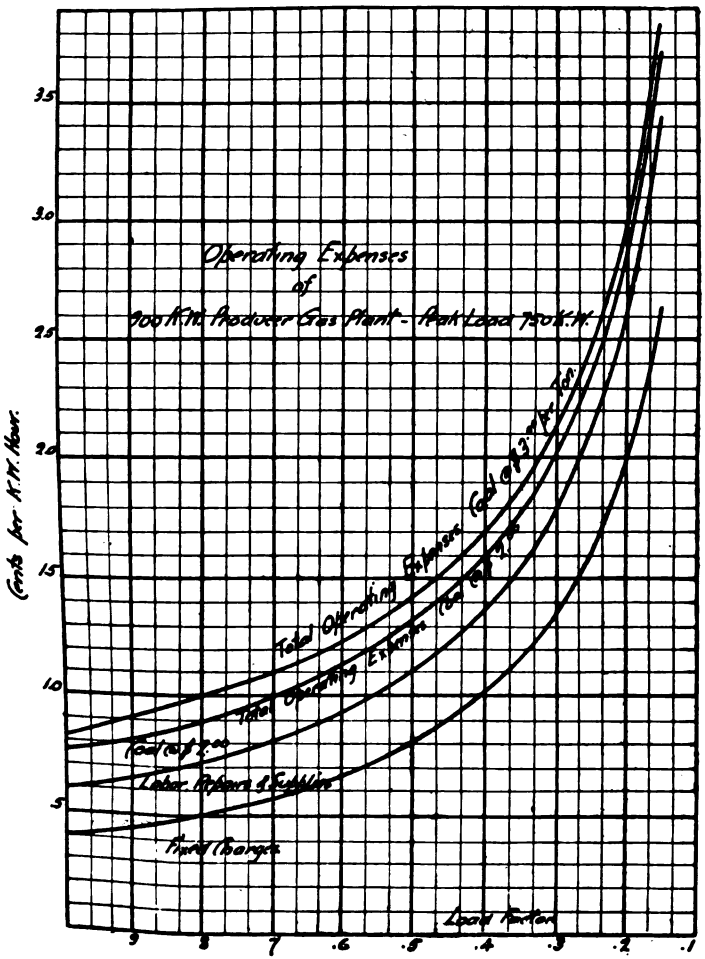

Fig. 8

of the same capacity as the rest, the cost being the same). In the first case at normal load on the generators the engines are 30% under-loaded with consequent poor efficiency; in the second case the first cost will be greater, due to the extra generator and increased size of building required.

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Allowing the same reserve capacity in producers, and with three 530 B.H.P. gas engines direct connected to 300 K.W. generators running at 100 r.p.m., the first cost becomes $167 650.00, equivalent to $186.00 per K.W.

Fixed charges:—

Interest at 5% on $167.650..	$8,382.50
Depreciation on machinery 10%..	13,340.00
Depreciation on buildings 3%..	1,005.00
Taxes and Insurance 2%..	3,353.00
Total..	$26,080.50

The storage capacity at 100% load factor is small, about 20,000 cubic ft., and is provided more for uniformity of gas than for storage. In case of accident to one producer, a second may be under way producing gas inside half an hour. The question of storage is important, particularly at small load factors when storage may be provided for the peak and a constant load maintained on the producers. In a plant of this size where the number of producers actually required is not over two with a third for reserve, it is more advisable to use the same number of producers for all load factors and a small amount of storage for uniformity of gas and sudden peaks. Further, the extra storage capacity required for small load factors costs about the same as an extra producer.

The operating costs for oil, water, repairs, supplies and water have been taken practically the same as for steam, as there is insufficient reliable data at hand on this subject at the present time.

Cost of labor is somewhat cheaper—for the type of producers considered only one man is actually required.

In fig. 8 are given curves for cost of power with varying load factor for this 900 K.W. gas plant.

A comparison of fig. 1, 2, and 8 shows a greater economy for the gas plant at the higher load factors, but poorer economy at low load factors due to the influence of the heavy fixed charges.

The higher the cost of coal the greater is the economy of the gas over the steam plant at high load factors.

It must be remembered that the fuel economy in the case of the steam plants is taken considerably higher than the average and can only be secured by constant and careful attention to all the details around a power plant; in the gas plant the fuel at 50% load factor is taken at 1.4 lbs. coal per B.H.P.Hour, which is somewhat higher than the manufacturers will guarantee. No matter how the fuel costs may vary from those given in these curves, they are relatively of far greater importance when the load factor is high than when it is low.

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PAPER No. 222.

THE ELECTRO-THERMIC PRODUCTION OF IRON AND STEEL.

By EUGENE HAANEL, Ph.D.

The iron and steel industry is the foundation of all other industries. To develop the former furnishes the means and incentive for the development of the latter. A country which requires to import its iron—the raw material for all industrial progress—is severely handicapped in the race for commercial success. It is only when a country is able to manufacture commodities beyond its need that exportation and expansion of trade become possible.

During the year 1903-1904 (Trade Navigation Report) Canada imported:—

Pig iron, steel ingots, ferros, scrap, etc...	1,727,867
Rails, bars and other manufactured iron and steel ..	12,172,082
Sheet iron and plates	5,223,250
Wires	2,216,413
Hardware	4,593,226
Agricultural and miscellaneous machinery	17,178,761
Total	$43,111,599
To ascertain sale value add 25%	$10,777,899
	$53,889,498

These figures show to what extent we are at present dependent upon outside sources for iron in the crude and manufactured state. The influx of settlers requiring tools and machinery, the building of new railroads, the displacement of wood by steel in modern architecture, the multiplication of established, and the inauguration of new industries will, in the near future, rapidly increase above the present demand the annual quantity of iron and steel required for home consumption. To stimulate and encourage the production of iron and steel for our abundant sources of raw material the Government has offered generous bounties on pig and rails produced in Canada, and placed an import duty on articles manufactured from iron and steel. Regarding the distribution of

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the raw material for the prouction of pig, the conditions of the country are, however, such that the necessary coking coal for blast furnace work is found only at the extreme east and west, while the large Provinces of Ontario and Quebec, possessing numerous and extensive deposits of iron ore, are without coal deposits. If these deposits are to be utilized in the production of pig by the present method of smelting, either coke must be brought to blast furnaces erected in the vicinity of these deposits, or the ore of these Provinces must be transported to blast furnaces erected near an abundant coal supply. In either case the transportation costs render such a course uneconomic. Unless some other method of smelting, in which some other source of energy than that resulting from the combustion of carbon in blast furnaces, can be proven to be practical and economic, the extensive ore deposits of these provinces will remain to a large extent undeveloped, and regions which might otherwise be made to teem with an industrial population, will remain waste areas for many years to come.

The necessity of profitably employing the electric plants erected in different parts on the Continent, especially in France, for the production of carbide, which had to be closed down as unprofitable on account of over-production, furnished the incentive to invent methods for applying electric energy; first,, to the production of the different ferros, and subsequently to the the production of pig and steel.

In the solution of the problem of applying electric energy to the extraction of metals from their ores, Captain Stassano in Italy, and Heroult and Keller in France, have rendered conspicuous service. The description of the experiments made by them and the results obtained attracted wide attention and were eagerly discussed in the scientific press, for it was at once seen that if by the electric process pig could be economically produced, such countries as Brazil, Chili, Sweden, Norway, Finland, and our own two provinces of Ontario and Quebec, all rich in iron ore deposits and the necessary fluxes, and possessing extensive water powers but lacking coal, would be able to render themselves independent of outside sources by employing the electro-thermic process for the manufacture of their iron and steel.

It was with a view of ascertaining the feasibility of introducing electric smelting into Canada, that the Honourable the Minister of the Interior appointed two separate Commissions to investigate this subject.

For a number of years the Ruthenburg process of electric smelting of magnetite had attracted attention. Papers on the subject were read by the inventor of the process in the meetings of the Electro-chemical Society, were seriously discussed by the

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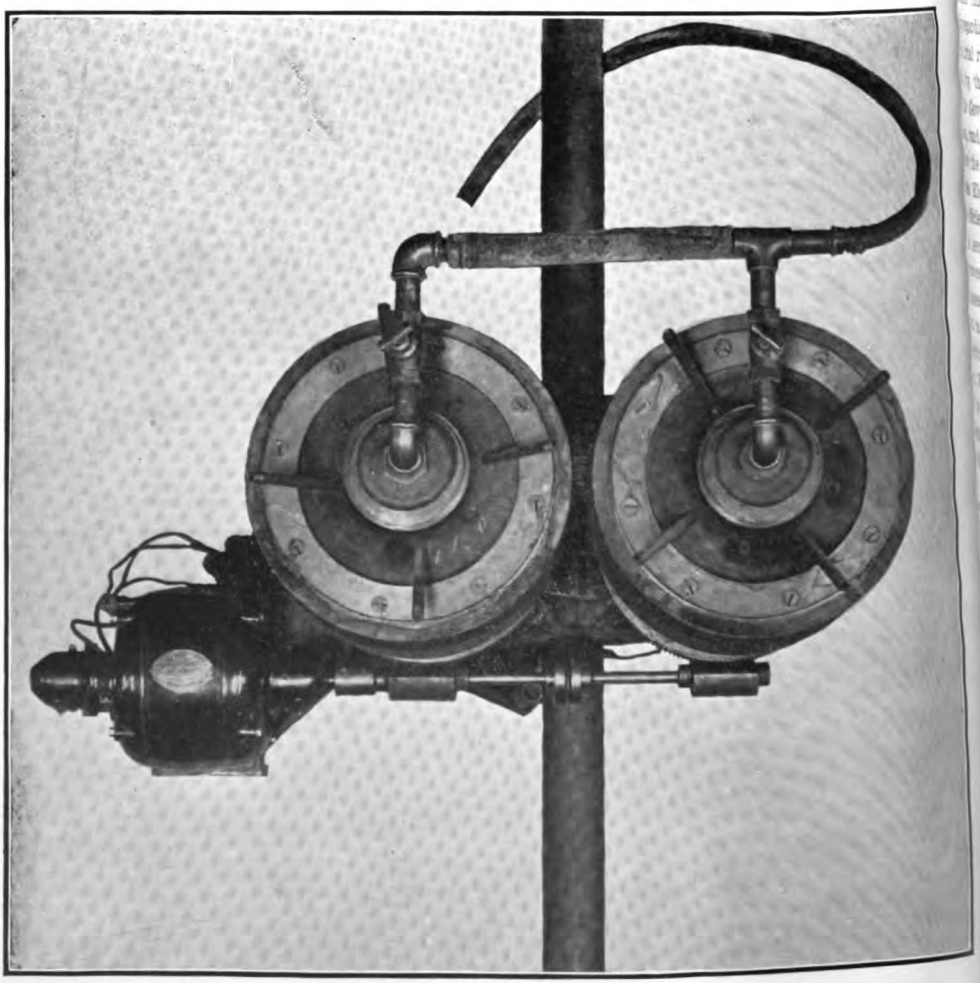

RUTHENBURG FURNACE.

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members of the society and published in their transactions, which gave to this process a quasi scientific sanction. No examination had been made of the process by any competent authority, and whatever had been published so far had been published on the statement of the inventor of the process. It seemed, therefore, desirable that the claims of the inventor, which were rather startling regarding the efficiency of his process, should be investigated by a trial run, and a Commission was appointed on the 2nd July, 1903, by the Honourable the Minister of the Interior, consisting of the Government Electrician, Mr. Higman, the Metallurgist, Mr. Locke, and myself, with instructions to proceed to Lockport, N.Y., where the Ruthenburg electric furnace had been set up in the Cowles Electric Smelting and Aluminum Works, and investigate the efficiency of his process.

A second Commission was appointed on December 28th, 1903, to proceed to Europe and investigate the different electro-thermic processes for the smelting of iron and the making of steel in operation in Europe. This Commission consisted of Mr. C. E. Brown, Electrician; F. W. Harbord, Metallurgist; Mr. Nystrom, Draftsman; Mr. Cote, Secretary, and myself.

In giving a short epitome of the work done by these two Commissions I will give, with your permission, the facts elicited in the order of the appointment of the Commissions.

First—The Ruthenberg Process of Electric Smelting of Magnetite.

Description of Furnace.

The furnace consists of an electro-magnet (horse-shoe pattern) of cast-iron, with pole-pieces of soft steel. The two limbs of the magnet are electrically insulated from each other at the behd, which, in the form of a joint, permits the variation of the gap between the poles by means of a screw. The limbs of the magnet are surrounded for nearly their entire length by closed brass drums, which are provided at the end farthest from the poles with means for rotating them towards the gap. The rotation is effected by a separate motor of about ¼ horse-power. These drums serve the double purpose of absorbing by water circulating through them the heat generated and of giving motion to the ore toward the gap. The parts of the drums to which the working current is distributed and which forms the electrodes are armed with carbon plates. The current was furnished by two Brush Direct Current generators, joined in series of 50 volts and 3,000 amperes capacity each, thus giving 100 volts and 3,000 amperes.

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A Weston ammeter of 4,000 amperes capacity, a Weston voltmeter, reading to 120 volts, and a Scheefer recording wattmeter, No. 42,203, specially constructed for 2,000 amperes at 110 volts, were in circuit with the main current.

Description of the Process.

The magnetite is first coarse-crushed and sent through Cornish rollers for fine crushing. From these it passes into magnetic separators, which eliminate the non-magnetic constituents. The resulting concentrates are mixed with carbon in amount somewhat in excess of the amount needed to reduce the ore to the metallic condition. Partial reduction of the ore is expected to be effected by the working current in the gap of the carbon-covered drums, where, on account of the magnetic field, the mixture of ore and carbon forms a bridge, the carbon being held in place by the magnetite threads which span the gap. The partially reduced ore in the heated condition loses its magnetism and drops into a cooling pit, being replaced by a fresh mixture of ore and carbon; the process is thus automatic and continuous.

The partially reduced and heated ore is expected to agglomerate into masses in the pit, where it is assumed to undergo further reduction. After the cooling, the fritted mass is, according to the patentee's account, melted in a cupola and cast into ingots, or directly transferred to an open hearth furnace and converted into steel.

Calibration of the Electric Measuring Instruments.

The calibration of these measuring instruments was undertaken by Mr. Higman, who employed for this purpose his own official standards. The Weston ammeter and voltmeter were found to be correct, but the wattmeter failed to record. Examination by the agent of the firm in St. Catharines revealed the fact that the lower ball-bearing of the spindle of the rotating disc was missing, and that the connection of the potential coil had been broken.

The wattmeter being of special design and not kept in stock, it became necessary to send it back to the factory in Peoria, Illinois. To avoid all unnecessary delay, Mr. Higman undertook to convey it to the factory and personally supervise its refitting.

Determination of Electric Energy Absorbed.

On the return of Mr. Higman with the repaired and calibrated wattmeter, it was decided to make a trial run of a quantity of

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ore sufficient to determine the electric horse power absorbed in the furnace per ton of product. The following mixture was employed by Mr. Ruthenburg for this purpose:—

Moisie Iron Sands	3,200 lbs.
Sawdust..	200 "
Coke, crushed	800 "
Total	4,200 lbs.

Before conveying this mixture to the bin, which was situated behind and above the furnace and supplied the furnace by means of a spout, the patentee plentifully sprinkled the charge with a watering pot, in the hope that the water would bind the ingredients of the mixture sufficiently to prevent their separation in the bin according to their specific gravities. This naturally imposed the additional useless burden upon the furnace of providing sufficient heat for the evaporation of such water.

On starting the furnace it was found that the resistance in the gap was so great, that with the available pressure of 100 volts only about 150 amperes, on an average, could be driven through the ore bridge in the gap, and even when the gap was narrowed to ⅛ of an inch, the current could not materially be increased. The uneven feeding and the uneven size of the particles of the mixture caused the resistance in the gap to vary to such an extent that the ammeter indications fluctuated rapidly througout the experiments 50 or even 0 and 200 amperes. Unfortunately the disc of the recording wattmeter remained stationary whenever the current strength fell below 150 amperes. From this it is evident that the wattmeter readings, as recorded by Mr. Higman, did not represent the whole electric energy absorbed. As the experiment progressed, it was found that the sawdust of the mixture was only partially acted on in the gap, particles passing through without having been carbonized, and the large pieces of coke, heated to a bright redness by the current, absorbed the electric energy without any useful return in effecting the reduction of the ore. The iron sands and coke particles fell in a fine, fiery rain into the pit, where they rapidly cooled, the iron sands having lost their magnetism before incipient fusion had set in, the product of the furnace in the pit failed to agglomerate into masses, and consisted apparently of nearly the same physical and chemical constituents as the ore mixture employed. After a period of 17 hours and 37 minutes, it was, therefore, thought a waste of time to continue the run, although a considerable quantity of the charge still remained

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in the bin. The furnace was, consequently, shut down, and the remaining charge run out and weighed.

The total amount of energy recorded by the wattmeter was 103 kilowatt hours, but since the meter failed to record when the current fell below 150 amperes, the record cannot be accepted even as approximately correct. 103 readings of the voltamperes had, however, been taken during the test, and these gave as the average rate of consumption per hour 17,400 watts, or a total during the 17 hours and 37 minutes of 306.5 kilowatt hours. Taking this last figure as the figure of the electric energy absorbed, the total quantity of ore treated in 17 hours and 37 minutes amounted to 1,732 lbs., or 1.18 tons per day of 24 hours, and the total electric energy expended in putting this amount through the furnace would be 417.6 kilowatt hours, which gives for one ton an expenditure of 0.054 horse power years.

The analyses made by Mr. Locke, the metallurgist, proved that the reduction, as was to be expected, was insignificant.

Conclusions.

Whatever the claims made by the patentee for this process, as exhibited to the Commission, the foregoing results of the investigation demonstrate its entire failure as a process for either agglomerating and fritting the finely divided ore, or for any useful reduction of the iron ore.

The fact that the magnetite loses its magnetism before incipient fusion takes place will prevent the agglomeration of the charge in the pit and the narrow gap between the poles, through which the charge requires to pass, will always render the capacity of the furnace small. These two facts preclude the hope that modifications of the process will render it commercially useful for agglomerating finely divided ore in substitution for briquetting.

Second—Experiments Made at Livet for the Production of Pig.

In the blast furnace process the coke performs two functions; that of reducing element and source of heat. In the electric furnace the heat derived from the transformation of electric energy is substituted for the heat derived from the combustion of carbon in the blast furnace, and only so much carbon is added to the charge as is required for the effective reduction of the ore and that required to enter into combination with the iron in the production of pig.

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Construction of the Livet Furnace.

The furnace is of the resistance type, and consists of two iron casings of square cross-section, forming two shafts communicating with each other at their lower ends by means of a lateral canal. The casings are lined with refractory material. Two different classes of funaces were used for the experiments. In the case of the first furnace employed, the lateral canal was widened out at its centre to form a reservoir for the accumulation of the melted metal, from which it could be tapped after the slag had been withdrawn from tap-holes, one for each shaft, situated at the lower end of the shaft, at a higher level than the tap-hole of the reservoir.

The base of each shaft is provided with a carbon block. These blocks are in electric communication on the exterior of the furnace by means of copper bars. The carbon electrodes, to which the electric current is distributed, pass two-thirds of their length into the shaft, and consisted of an assemblage of four electrodes of square cross section, 280 millimeters on the side, into a single mass of square cross-section, 850 millimeters on the side, and 1.4 meters long.

Method of Charging.

In starting the furnace, the charge is introduced between the carbon blocks of the base and the ends of the electrodes, which latter are then in their lowest position. The current passes from one electrode through the material to be reduced to the carbon block, from thence outside of the furnace by means of the copper conductor to the other carbon block, through the charge in the second shaft, and to the other electrode, the current meeting in the two shafts with the resistance of the charge. The latter is heated, the reduced metal flowing along the canal conducts the electric current from one electrode internally to the other electrode. The exterior current diminishes as the amount of reduced metal increases. The electrodes are now raised, the charging continues, until finally the electrodes occupy their normal positions, and the shafts below the electrodes and between the electrodes and the sides of the shafts are completely occupied by the charge. Under these conditions but a small current flows through the external conductor, the main current passing within the furnace from electrode to electrode. This ingenious arrangement of providing a shunt for the current enables the furnaces to be worked continuously, without at any time varying excessively the load on the alternator.

The iron ore, flux and coke, broken so that all would pass through a one and half-inch ring, mixed and conveyed to a platform

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surrounding the throat of the furnace, were charged into the furnace by hand labour. The waste gases were allowed to escape and burn at the top of the furnace.

The composition of the charge in the first set of experiments consisted of:—

Ore	500	kilograms,
Coke	100	"
Limo	60	"
Quartz	30	"

The resulting iron was very grey, containing considerable of both silicon and manganese. The coke was, therefore, reduced to 90 kilograms, the lime to 30, the quartz to 10, and still later the quartz was entirely omitted. The iron was low in phosphorus and sulphur.

Tappings occurred every two hours, and the molten metal was run into clay lined, horizontal, cast iron moulds. The length of run was 55 hours. Amount of pig produced was 9,868 kilograms.

The furnace worked quietly throughout the experiments, and without the slightest accident, although the current reached 12,000 amperes in one set of experiments. The carbon monoxide burned on top of the furnace in flickering flames, showing that the gas resulting from the reduction of the ore escaped without pressure. The workmen were ordinary Italian labourers, without any special training.

The electric energy expended per ton of pig in these experiments was .475 horse power years.

In a second set of experiments the charge had the following constitution:—

Ore	525	kilograms.
Coke	95	"
Lime	15	"

This was, towards the close, altered to:—

Ore	500	kilograms.
Coke	102.5	"
Lime	25	"

The electric energy expended was 0.226 horse power years per ton of pig. The length of run was 48 hours. Amount of pig produced was 6,692 kilograms.

For the first set of experiments the alternator furnishing the current was a revolving field machine with 16 poles, and rotating at approximately 380 revolutions per minute, with a periodicity of

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50 cycles per second, and was direct connected to a horizontal shaft water wheel controlled by a governor. Mean voltage 59.1.

For the second set of experiments the alternator employed was operated at about 280 revolutions per minute, giving a periodicity of 37 cycles per second. Mean voltage 55.3.

In ascertaining the electric energy absorbed when an alternating current is employed the volt-amperes read from the switch-board instruments do not furnish the watts delivered, since, on account of the reactance of the circuit, the amperes are not in phase with the volts, but lag behind the volts. It is, therefore, necesary to determine the cosine of the angle of lag, or, as it is otherwise expressed, the power factor must be ascertained, that is, the figure by which the volt-amperes require to be multiplied in order to furnish the watts delivered. This determination was made for us by the Director of the Electrotechnical Institute of the University of Grenoble for the two machines employed in furnishing the current for the two separate sets of experiments. The voltmeter and ammeter in circuit with the furnaces were also calibrated by the same high authority.

To render ourselves independent of the switch-board instruments in the determination of the electric energy absorbed, a Thompson recording wattmeter, rented from the Compagnie pour la Fabrication des Compteurs, Paris, and calibrated by them, was intercalated in the circuit, although this necessitated the cutting of the heavy copper bars carrying the current, and greatly inconvenienced the firm who were good enough to go to the trouble and great expense of making these experiments for us.

Quality and Kind of Pig Iron Produced.

By adjusting the charge it was easy to obtain any grade of pig iron desired, grey, white or mottled, and castings were made direct from the molten metal of the furnace, such as columns, gear wheels, plates, etc., all showing sharp edges and comparatively smooth surfaces.

Cost of Production of Pig by Keller Process.

Mr. Keller's estimate of cost per ton of product, based on the energy consumed in the second experiment and found to be 0.226 electric horse power years, is as follows:—

1.	Ore (Hematite, 55% iron) 1,842 tons @ $1.50 per ton ..	$ 2.76
2.	Coke, 0.34 tons @ $7.00 per ton	2.38
3.	Consumption of electrodes, $45.00 per ton, 34 lbs. per ton of iron	0.77
4.	Lime, 300 lbs. at $2.00 per ton..	0.30

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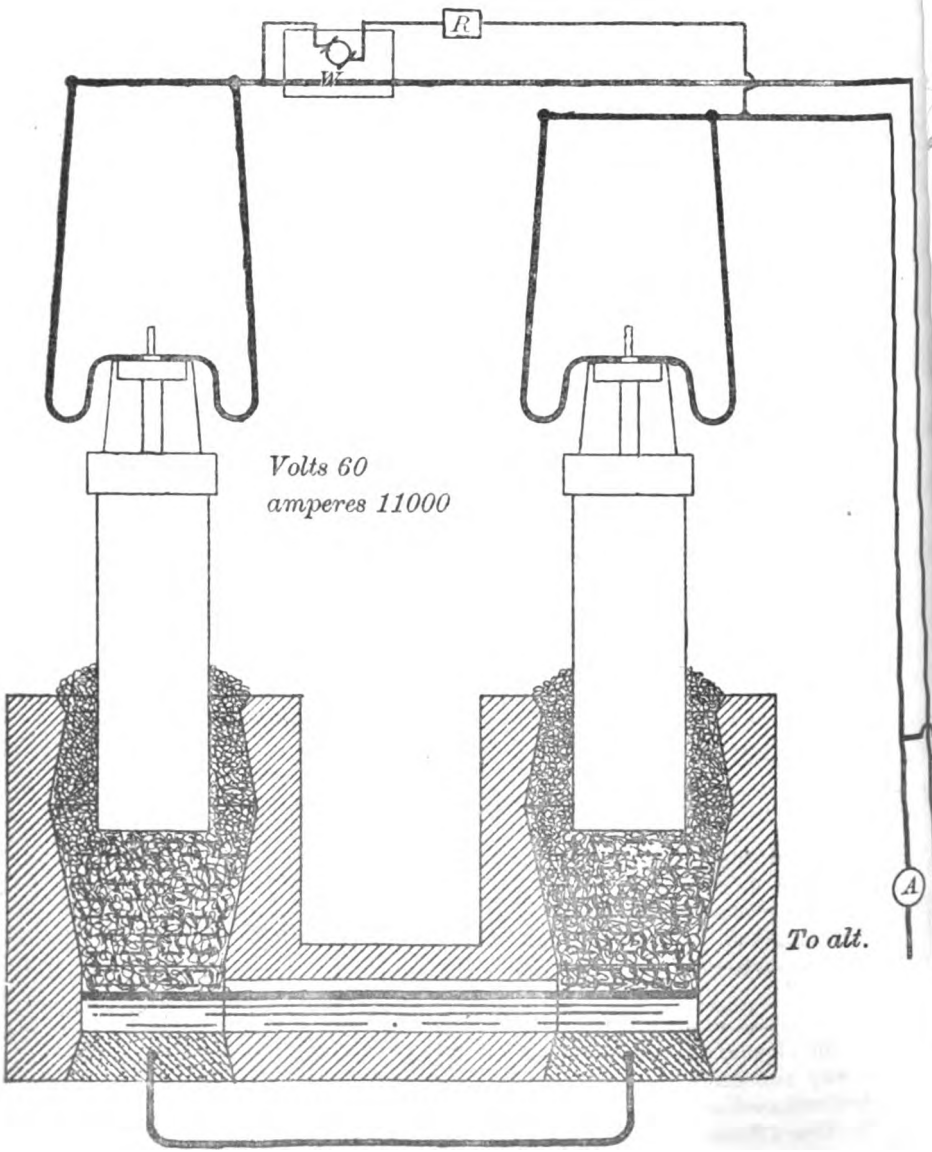

KELLER FURNACE.

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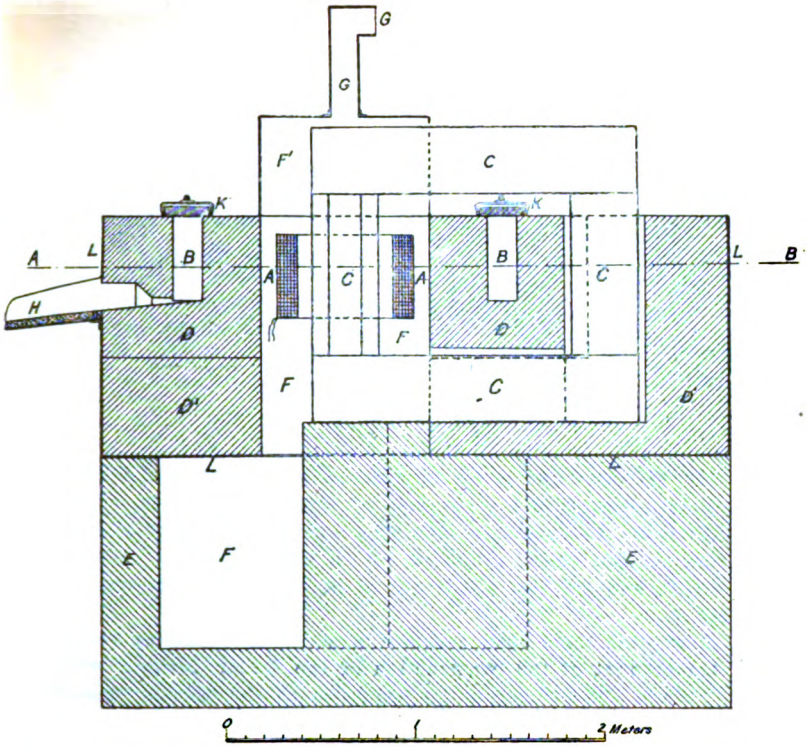

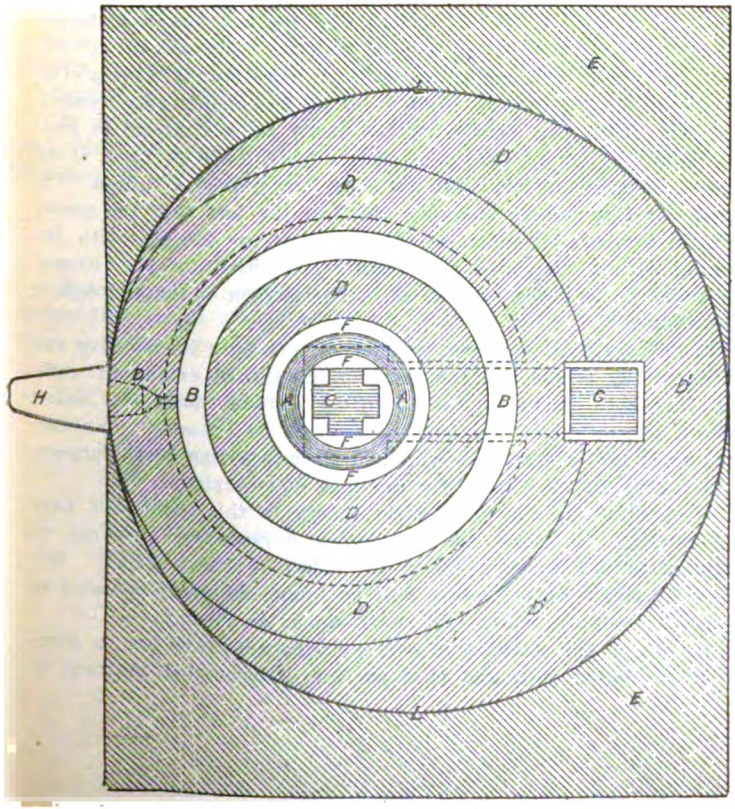

KJELLIN FURNACE.

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5.	Labor at $1.50 per day	0.94
6.	Electric energy 0.226 h.p. years at $10 per h.p. year	2.26
7.	Miscellaneous materials	0.40
8.	Repairs and maintenance	0.20
9.	General expenses	0.20
10.	Amortization (machinery and buildings)	0.50
	Total, exclusive of Royalty	$10.71

Mr. Harbord has furnished reasons for assuming the mean of the determination of the two sets of experiments made, i.e., 0.350 E.H.P. years, to be a safer figure on which to base the calculation of cost per ton of pig produced. With this change in the amount of E.H.P. and 100 lbs. additional of lime, the cost per ton of pig is $12.05.

Regarding these costs I desire to make the following remarks:

On account of the construction of the Keller furnace with a short shaft, the utilization for reduction of the carbon monoxide evolved has been very small, only 19.5% of the weight of the carbon theoretically necessary for the reactions effected was utilized as carbon monoxide. By increasing the length of the shaft and providing the upper part of the furnace with gas collectors for the purpose of utilizing the escaping gases for the preliminary drying of the charge the electric energy required would be considerably lessened. Moreover, instead of employing the costly coke, charcoal or peat-coke might be employed. Experiments were made at Livet at my request, substituting charcoal for coke, but proved a failure. The reason for this failure is easily found in the fact that the porous charcoal coming in contact at the throat of the furnace with the burning carbon monoxide was readily consumed by the oxygen condensed in its pores, as well as by the oxygen of the atmosphere surrounding it.

If the charcoal had been briquetted to reduce its porosity and gas absorbing power and the shaft of the furnace made of sufficient length to discharge the resulting carbon monoxide below ignition temperature, charcoal, which can be cheaply manufactured from mill refuse, but which is useless in the blast furnace, could readily be substituted for the coke now employed.

Regarding the cost of electric energy in this country. I have been credibly informed that an electric horse power year can be furnished by the development of the Chats Falls at $4.50. Undoubtedly many water powers will be found, favorably situated as regards ore supply, which can be developed as cheaply.

If then in our estimate of cost we substitute $5.00 for an Electric Horse Power year and $4.00 per ton of briquetted charcoal or

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peat-coke and allow for the saving in electric energy by a more economic use of the carbon monoxide produced in the furnace to be constructed with longer shafts and provided with appliances for saving the furnace gases, we would arrive at a very economic figure at which pig can be produced, something like $9.28 per ton.

I desire here to emphasize that every step in the experiments made at Livet has, as far as practicable, been carefully checked.

Third—Manufacture of Steel by the Gysinge Process.

At the Gysinge works in Sweden steel of a superior quality is made in electric furnace of the induction type.

Description of the Furnace.

The furnace consists of a cylindrical iron casing partly closed at the base, resting upon a brick foundation. The casing is lined with fire brick and that part which contains the annular groove is filled in with magnesite or silica brick, according as a basic or acid lining is required for the groove which forms the melting space or crucible. In the centre, and coaxial with the annular crucible the primary is placed, to which is distributed an alternating current of 90 amperes at 3,000 volts, which induces in the secondary formed by the metal in the annular crucible a current of 3,000 amperes at 7 volts. The conversion of electric energy into heat takes place, therefore, in the substance which fills the annular crucible.

Process.

The process, as carried out at Gysinge, consists in melting together Dannemora charcoal-pig and Walloon scrap in such proportions as will insure the proper carbon content in the steel produced.

The following is the composition of the charge for the steel of their usual manufacture:—

White pig iron	300 Kgs.	—C. 4.40 %
Steel scrap	125 "	S. 0.015%
Bar scrap	600 "	P. 0.018%
Metal in furnace	700 "	—C. 0.2 %
Silicon pig	30 "	S. 0.003%
Ferro-Manganese	1 "	P. 0.009%
	1,756 Kgs.	

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The crucible is never emptied completely, but about 700 kgs. are left in it at each tapping to maintain the current.

The time required for melting down this charge and getting it to the proper temperature is six hours, when it is tapped into ladles and teemed into iron moulds. The electric energy required per ton of product is 0.116 E.H.P. years.

Experiments Made.

Three different grades of steel were made for the Commission:

1st: The regular steel with carbon content of 1%, for which the furnace had been specially designed. Electric energy required per ton 0.116 E.H.P. years.

2nd: A steel containing about 0.5% of carbon, which was obtained without difficulty, but at a greater expense of electric energy. The electric energy per ton required for this steel was 0.145 E.H.P. years.

3rd: A very mild steel containing about 0.1% of carbon. This grade of steel was produced with considerable difficulty. The electric power necessary to bring the contents of the crucible up to the proper tapping heat was not available.

Quality of the Steel.

The experiments made with the Gysinge steel containing 1% of carbon at the Woolwich Arsenal proved the steel to be equal to the best crucible steel manufactured.

Electrical Measurements.

In order to be independent of the switch-board instruments for the measurement of the electrical energy absorbed in the manufacture of steel at Gysinge, standard volt and ammeters and a wattmeter were rented in Stockholm and placed in circuit.

The electric current delivered to the furnace is obtained from a single-phase revolving field alternator, rated at 3,000 volts and 90 amperes. It is a 24 pole machine with a speed of about 75 revolutions per minute, giving a periodicity of 15 cycles per second. It is arranged with a vertical shaft direct connected to a water wheel.

The low power factor (average of first run 0.672) and the low periodicity of the alternator are disadvantages which are inherent to the system employed, but the fact that the furnace takes current directly at a voltage suitable for generation and transmission over moderate distances, requiring neither carbon, special connections, nor electrodes, with their attendant cost, loss of power and necessity of attention, is an important advantage.

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Cost of the Steel Produced.

Materials	$31.66
Wages..	2.66
Renewals and repairs...	0.60
Electric energy..	1.48
Ingot moulds	0.48
Interest and redemption	0.60
Per metric ton	$37.48

or $34.00 per ton of 2,000 lbs.

General Remarks.

The process as practiced at Gysinge with the present construction of the Kjellin furnace does not permit the purification of the materials employed. The quality of the steel depends entirely upon the purity of the component materials employed. On the other hand this process is especially adapted for the manufacture of high grade carbon steels and high speed steels, such as tungsten and molybdenum steels. The heat is generated within the material itself, and not subjected to absorption of gases nor impurities from electrodes.

The capacity of the furnace at present employed is small, the output being a little over four tons per 24 hours. For a larger plant, Mr. Kjellin proposes that three furnaces of 15 tons capacity each of the pattern now used be united into a compound furnace, each separate furnace surrounding a leg of a three phase transformer and made common in the centre.

FOURTH—THE HEROULT STEEL PROCESS AT LA PRAZ.

At La Praz steel of different grades is made from miscellaneous scrap by the Heroult Process.

Description of Furnace.

The furnace is of the tilting pattern, in shape much like the tilting Campbell furnace.

It consists of iron casing lined with dolomite brick and magnesite brick around the openings. The hearth is formed of crushed dolomite, rammed on top of the dolomite brick-lining of the bottom of the iron casing. Two electrodes pass through the roof of the furnace, which, in the Kortfors furnace, were water jacketed for a short distance above and below their passage through the iron casing of the roof. The current passes from one electrode

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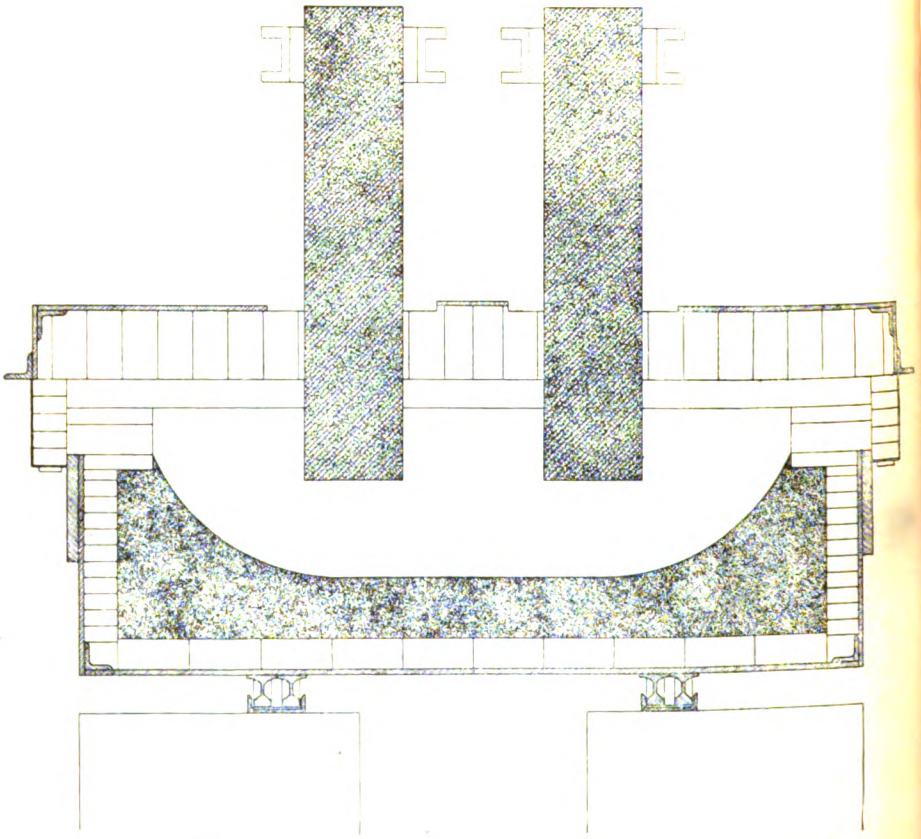

HEROULT FURNACE.

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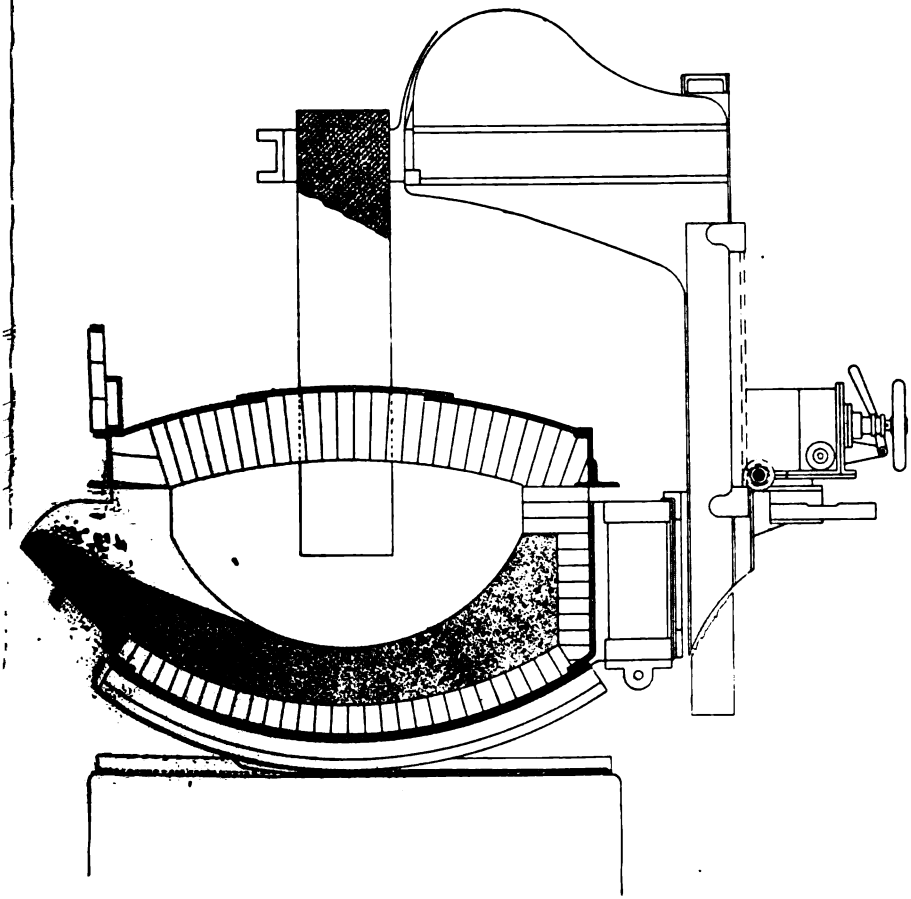

HEROULT FURNACE.

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through the narrow air gap left between the electrodes and the slag line, into and through the slag to the molten metal, along it, through the slag and the second air gap, to the other electrode.

Electrodes.

The electrodes are square prisms 360mm. on the side and 170cm. long. They are made from retort coke which contains from 1% to 2% of sulphur. The binding material is tar.

Process.

The scrap is charged through the doors with some lime melted down and purified by the making of a number of slags and carburized in the furnace by carburite.

Measurement of Electric Energy.

The electrical readings were taken on the regular switch-board voltmeter and kilowatt-meter. No ammeter was in circuit. The average voltage was 110 volts, the mean kilowatts, full gate open, were 340.

An automatic regulator controlled the position of the electrodes relative to the bath, and kept the voltage between them and the bath constant. Two volts difference either way brought the regulator into action. Whenever the current fluctuated violently, as in the melting down of the scrap, the automatic regulator could be switched out and the regulation effected by hand.

Experiments Made.

The following experiments were made for the Commission: 1st: Low carbon steel for transformers.

The following is the composition of the charge:

Miscellaneous scrap	3,307 lbs.
Iron ore	330 "
Lime..	246 "

The scrap had the following composition:—

C. =	0.110		C. = 0.079
Si. =	0.152		Si. = 0.034
S. =	0.055		S. = 0.022
P. =	0.220	Steel produced.	P. = 0.009
Mn. =	0.130		Mn. = 0.230
As. =	0.089		As. = 0.096

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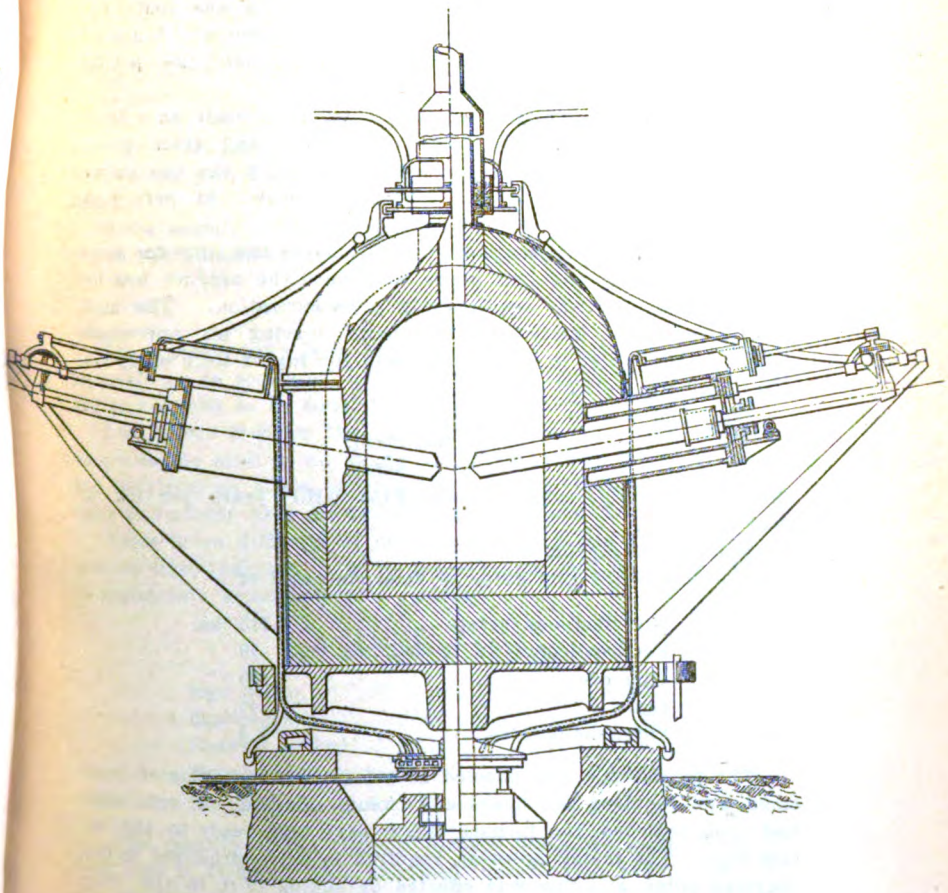

STASSANO FURNACE.

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When metal and slag had been completely melted the slag was poured off, great care being taken to ensure the complete removal of the slag. A new slag was then made by adding 55 lbs. of lime, 15.5 of sand and 15.5 lbs. of fluorspar. This was melted and kept in the furnace for some time. It was then poured off, and the last traces of it raked off from the surface through the pouring door.

A third slag of similar composition was then made as a finishing slag to remove the last traces of impurity, and then poured off. 1.5 lbs. of ferro-manganese were added and the charge was poured into a ladle and a little aluminum thrown in before the metal was teemed into ingot moulds.

On account of the smallness of this charge the time for working was only four and half hours, and since the product was low in carbon no time was required for re-carburization. The steel, when teemed, ran freely from the ladle, leaving no appreciable scrap. It was quiet in the moulds, and the ingots were exceptionally sound for steel of this quality.

The yield was:—

2,820 lbs. ingot.
9 " scrap.

The electric energy consumed was 0.153 E.H.P. years per ton of steel produced.

2nd: High carbon steel.

The charge for this grade of steel consisted of:—

Miscellaneous scrap	5,733 lbs.
Ferro-silicon..	19 "
Iron ore	430 "
Lime.	346 "
Ferro-manganese	3.3 "

The purification was effected as before by the making of three slags, and required five hours and twenty minutes. If soft steel had been required, the furnace would have been ready to tap at this time. The metal, however, required to be re-carburized to the required point, and this was effected by adding to it in the furnace "carburite," a mixture of pure iron and carbon. 19 lbs. of 13% ferro-silicon were added at the same time. The charge was sampled in the usual way with a spoon ladle, and when the furnace man was satisfied that the bath contained the required amount of carbon, the metal was poured into the ladle, a little aluminum added and teemed into ingot moulds. The metal ran very freely, leaving no skull in the ladle, was quiet in the ingot moulds, and forged extremely well.

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Composition of the Steel Produced.

C.	1.016
Si.	0.103
S.	0.020
P.	0.009
Mn.	0.150
As.	0.060

Time for working, 8 hours.

Electric energy consumed, 0.153 E.H.P. years per ton of steel produced.

If the metal had been tapped before re-carburization the electric energy consumed would have been 0.1 E.H.P. year per ton.

Quality of the Steel.

These steels have been examined for us regarding their wearing qualities as tool steel by the officers of the Woolwich Arsenal and pronounced to be equal to the best crucible steels.

I may here mention that for lathe tools in large machine shop crucible steel is no longer employed as tool steel; Tungsten and molybdenum steels, or what are termed high speed steels, being exclusively used for lathe, planer and similar tools.

There is no difficulty of producing these steels by the Heroult process, ferro-tungsten or ferro-molybdenum need only be added in appropriate amounts before casting.

Cost per Ton of Product.

Raw scrap.	$12.00
Electrodes.	.20
Electric energy	1.53
Repairs and renewals	1.40
Labor...	1.86

The capacity of the Heroult furnace described is small, about four tons in 24 hours; this has been increased to seven tons by the addition of water-jackets around the electrodes, but without altering the design of the furnace, its capacity could readily be increased to 15 tons.

Fifth—The Direct Manufacture of Steel by the Stassano Process.

To put carbon into iron in the production of pig and take it out again by a second process in the manufacture of steel appeared to Captain Stassano an irrational and uneconomic proceeding, and he

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devised, therefore, a method for making all grades of iron and steel direct by one operation. For this purpose the quantities of ore, flux and carbon are calculated out to furnish by reaction the class of iron and steel required, briquetted and subjected to the heat of the electric arc in his furnace.

Description of Furnace.

The furnace is of the arc type, and consists of a cylindrical outer casing of iron surmounted by a conical roof. The furnace is lined with formed magnesite brick. The axis of the furnace is inclined to the vertical by a small angle, and during the operation of smelting the furnace rotates about its axis, thus agitating the charge and bringing constantly new material to the surface to be subjected to the radiation of heat from the arc, which assists greatly the reactions which require to take place in the reduction of the ore.

A three-phase alternating current of 90 volts between the phases and 400 amperes is distributed to the three electrodes which nearly meet in the centre of the interior of the furnace. Their distance apart is varied, as required, by a hydraulic regulator.

Since nothing is present except heat and the materials which enter into the charge, the calculations and results should agree. This Captain Stassano has demonstrated to be really the case by an elaborate set of experiments, and on the table before you are one of his briquettes and some samples of steel made by his process in one operation direct from the ore.

The Commission has unfortunately not been able to make a trial run and determine experimentally the figures which enter into a determination of the cost of product by his process, since his furnace was out of repair, the roof lining having fallen in and the refractory bricks ordered from Austria for repair not having arrived. And while I cannot, therefore, speak with authority about the efficiency of his process, we need to be reminded that a metallurgical process, which appears to be more simple than another process, is not, therefore, necessarily the more economic. The following are some points which occur to me, regarding this process, which would militate against the economy:—

1st: On account of the position of the source of heat above the charge, the reduction of the ore requires to be performed by the solid particles of carbon, producing carbon monoxide. This carbon monoxide so formed can take no further action in the reduction of the ore, since at the temperature within the furnace carbon dioxide could not be formed, and hence the reducing power of the carbon monoxide, which must escape as such at the throat of the

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furnace, is not alone not utilized, but the gas escapes at a high temperature, which entails great loss of heat. The electric energy required for reduction will, therefore, in this class of furnace exceed that required in furnaces which permit the heated carbon monoxide to rise through a column of the charge of sufficient height to utilize a minimum of its reducing power.

2nd: The process is discontinuous, the charging requiring to be done through side doors beneath the electrodes, after tapping the slag and metal.

3rd: On account of the construction the capacity of the furnace will not exceed 10 tons of product.

With respect to the economy of this process, Dr. Hans Goldschmidt, who has investigated the process, expresses himself to me in his letter of March 8th in the following words:—

"A method which would enable us to produce steel directly from the ores by means of the electric process has not been worked out and tested sufficiently so as to be able to erect extensive plants without undue risk."

General Remarks.

The modern blast furnace and the different methods for the making of steel, as at present employed, are the results of a hundred years of experience, and have reached their present perfection through many modifications, which in many instances were accepted and introduced into practice only after much hesitation and opposition. The electro-metallurgy of iron and steel is of very recent date, and although high class steel has been commercially produced and put upon the market for a number of years, no plant as yet exists where iron ore is commercially reduced to pig by the electric process.

But when we consider that the experiments made at Livet were made in furnaces not at all designed for the production of pig, and furnished a figure of cost which permits comparison with the cost of pig iron produced by the highly developed metallurgical appliances, the blast furnace, we have every reason to expect that the electro-thermic process for the production of pig will be successfully introduced in regions where water power can be developed cheaply in the immediate neighborhood of extensive iron deposits. When it is further understood that the electric process is applicable also to the smelting of ores, such as copper, nickel, etc., that the furnaces are of simple construction, the temperature available 1,000° above that of the blast furnace, and the regulation of the heat supply under perfect control, we may expect that the near future will witness great strides in the application of electric

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energy to the extraction of metal from its ores, and that familiarity with handling large currents, and experience gained in electric smelting will result in solving the difficulties encountered in the smelting of ores, which up to the present time have proven refractory to all economic processes known. I need only mention that the treatment of the highly titaniferous iron ores, of which enormous deposits exist, have resisted successful treatment by the blast furnace method of smelting. Mr. A. H. Allen, of Sheffield, who has made experiments in this direction, states:—"That by making a highly acid slag it was possible to smelt such ores, though resulting in the wear and tear and detriment of the blast furnace, and of the blast furnace manager."

Mr. Keller, of Livet, however, has shown that the New Zealand iron sands, which contain 9.3% of titanic acid, can be treated with perfect success in the electric furnace by the employment of an ultra-basic slag and extreme hot working. The slag took up the whole of the titanic acid, and was found on analysis to contain 14% of it. Of course, such ultra-basic slag, on account of its high melting point, could not be rendered fluid with the temperature available in the blast furnace.

Regarding the conclusion arrived at by Mr. Harbord, the Metallurgist of the Commission: that at present structural steel to compete with the Siemens or Bessemer steel cannot be economically produced in the electric furnaces, and such furnaces can be used commercially for the production of only very high class steel for special purposes, it is important that the emphasis be placed on the words "at present." His conclusion is based upon the furnaces examined by us, the capacity of which was small, as it always is with appliances for the exploitation of new processes, but there is nothing inherent in the nature of electric furnaces which would prevent their being constructed of sufficient size to have a capacity equal to the Siemens open hearth furnace, and the engineering difficulties which may present themselves in arriving at a modification of design necessary for such increase of capacity are not likely to be found insuperable. We need only look back in the history of metallurgical appliances to note in almost every instance the gradual increase in capacity from a very small output at the beginning.

Thus, the size of blast burnaces toward the close of the 16th century permitted only an output of three-quarters of a ton per day of 24 hours. This increased in 1,800 to 3.3 tons per day and iron men of that day would have though it incredible, perhaps impossible, to increase, as is now done, the capacity of the blast furnace to 500 tons per day.

Again, 30 years ago 30 tons of copper per 24 hours was re-

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garded as fair duty for a copper furnace; to-day such furnaces have a daily capacity of some 300 tons. The original Siemens open-hearth furnaces (1868) had a capacity of only three or four tons; modern furnaces have a capacity of 40 to 50 tons.

In view of this, who is to say that structural steel cannot be made in electric furnaces simply because the present furnaces have, as is natural in all beginnings, a small capacity.

There is no question in my mind that we are on the eve of great achievements as regards the application of electric energy to the extraction of metals from their ores and that the energy of the splendid, abundant, and as yet undeveloped water powers of Canada will ere long be employed for metallurgical purposes.

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MINING SECTION.

President—J. B. PORTER.
Vice-President—K. W. BLACKWELL.

A meeting was held Thursday, February 9th, 1905, Dr. J. B. Porter in the chair. The following paper was read:—

PAPER No. 223.

THE MINE FIRE AT DOMINION NO. 1 COLLIERY, GLACE BAY, N.S.

By SHIRLEY DAVIDSON and NORMAN MCKENZIE.

Dominion No. 1, which is one of the oldest collieries in Cape Breton, was first mined by the General Mining Association in 1831.

It was abandoned for some years prior to 1893, when it passed under the control of the Dominion Coal Company, which sunk the present coal, air, and material shafts and equipped the mine with the most modern machinery, such as endless haulage systems, compressed air, self-dumping cages, electric haulage and electric lighting. The mechanical equipment on the surface consists of: Babcock & Wilcox boilers, of 1,696 rated H.P.; one coal hoist engine; one man hoist engine; two 26" x 60" haulage engines; three fans, 24 feet, 12 feet, and 8 feet, respectively, with capacities of 200,000, 75,000 and 25,000 cubic feet of air per minute; three air compressors in three units of 2,600 cubic feet each per minute; and one 100 K.W. electric 250 volt generating unit.

The bankhead consists of a steel structure equipped with up-to-date appliances for picking and screening the coal and delivering it to coal cars, and also to the colliery boilers and locomotives by means of 14" and 12" Robins Belt Conveyors.

Underground there are in use 62 horses, 46 mining machines and 340 pit tubs.

The colliery at the time of the fire was producing on an average 55,000 tons of coal per month, and employed about 800 men.

There are three shafts sunk and used severally for coal, air and material. The main or coal shaft generally used as an upcast—although the current may be reversed—is 154 feet deep from surface to rail, 10½ feet wide by 24 feet long, and consists of three compartments, two for coal and one for men. It is sunk below the pavement to a depth of 7 feet in order to bring the cage platform

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level with the mine track. The Fan shaft, 143 feet, 11 feet in diameter, can be connected to either of the three fans, and is generally used as a downcast. The material shaft, 135 feet deep, is 10 feet wide by 18 feet long, and is also used for the endless haulage ropes, which are brought to the engine house located on the surface directly alongside.

These shafts are sunk about 1,900 feet from the crop. The surface in the vicinity is 89 feet above sea-level, while the pavement is 68 feet below sea-level. The surface from the shaft slopes gently to the shore line of the Atlantic ocean, distant 1,800 feet, where it breaks away abruptly in low cliffs, exposing the seams of coal and the remains of some old workings, supposed to be those of the French many years ago.

The seam worked, which is remarkably exempt from upthrows or downthrows, is known as the Phalen. It averages about 8′ 4″ of clear bituminous coal.

The dip of the seam is in an easterly direction, the angle or inclination of dip being about 1 in 15. The floor of the mine is a very gritty shale, and the immediate roof is also a shale, which readily falls at times, but is easily supported by timber. The plan of working is the ordinary "room and pillar"; the deeps, headways and levels are driven 12 feet wide, and the rooms 22 feet wide.

The size of the pillars left at present is 25 x 70. The present faces of the workings have reached a distance from the shaft of 5,700 feet in the North deep, 5,400 feet in the South deep, and 3,000 feet in the Angle deep.

The overhead cover at the face of the North deep is 519 feet in thickness of strata.

The mine made some 500 gallons of water per minute, but had also to take care of 800 gallons per minute from the Main and French slopes of Reserve, which quantity passed through a borehole in the barrier separating Dominion No. 1 from Reserve, and flowed along No. 3 South level to the water lodgement on the back North deep, from which it was pumped to the lodgement at the shaft bottom through a 7″ pipe. There are three water lodgements in the pit. One of 500,000 gallons capacity is located at the shaft bottom, one of 500,000 gallons capacity is about 2,000 feet from the shaft on the North back deep, one of 900,000 gallons capacity is at the face of the South deep as shown on the plan. The first two are connected as noted above, by a 7″ pipe laid up the North Main deep, the lower pumping into the upper from two 14 x 8½ x 33, three hundred gallon Cameron pumps: the upper then discharges vertically up the shaft to the surface through one 300 gallon Cameron pump. The lodgement at the face of the South Deep contains a 1,000 gallon duplex pump, which discharges vertically 430 feet through a

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borehole into International Mine, from whence it flows by gravity to the sea. Another borehole driven from the surface, 519 feet in depth, contains the steam and the exhaust pipes one within the other. Steam is supplied by the boilers at International Mine, located on the surface almost directly overhead.

The underground workings of Dominion No. 1 cover an area of 560 acres, and had produced from this area while under the management of the Dominion Coal Company, approximately 3,400,000 tons up to the time of the fire.

Inflammable gas is met with in very small quantities in the workings, but a sufficient amount of ventilation is maintained by a powerful 24 feet Dixon fan, which circulates 114,000 cubic feet of air per minute with one inch water gauge.

A water service is maintained for boiler supply and other purposes on the surface through a 6" pipe leading from a small stream distant about a mile from the Colliery. An efficient supply is kept up by a 250 gallon 14 x 8 x 12 Knowles pump. The stream is dammed, and forms a reservoir capacity of 7,000,000 gallons on the edge of which is located the boiler, pump and pump-house.

About 3.30 in the morning of Thursday, March the 19th, 1903, a workman returning from work discovered fire in a cross-cut between the Back and Main North Deeps near No. 3 Landing, about 1,200 feet from the shaft bottom and about 147 feet below sea level. The opinion is that it was started on the back deep side of the stopping by a workman carelessly throwing away the lighted wick from his lamp, or, contrary to all rules and regulations, kindling a fire in order to warm tea. This back deep is used as a travelling road, and the stopping in question was the same as all others built in the cross-cuts in the pillar between the Back and Main North Deep. It was composed, as most of them are, of hemlock boards lined with brattice cloth: the average width of this particular cross-cut was 12 feet. Some loose boards were lying alongside, and it is probable that some rubbish had also collected, as is generally the case in the waste places of mines. On account of the location, the fire was an exceedingly difficult and dangerous one to deal with. Alongside of it to the North was an old and abandoned section, where some time previously a bad crush had made it necessary to protect the pillars along the travelling road with a considerable number of props lagged behind. The workman who made the discovery, instead of making any attempt to stamp out the fire, as might have been done in this early stage, fled to the shaft bottom. This he reached after a difficult passage through the smoke, which quickly collected and poured up both North Deeps with the air current to the shaft.

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He gave the alarm to the Underground Manager, who with an Overman immediately travelled directly towards the fire, through the smoke, on the Back Deep. Orders were given to the bottomers to follow down with buckets. When within seven hundred feet the glare of the fire was dictincly seen, extending across the Deep, and when the cross-cut was reached, the place was a mass of flames, and the top of the coal was scaling.

A shovel—the only appliance at hand—was of no practical use; it was impossible to get about the fire, on account of the dense smoke, and the Underground Manager, seeing that the fire was beyond his control, with the limited assistance of one or two men at hand, made for the shaft bottom for proper appliances and more help. The men at the bottom refused to give this, so he started back alone, but this time by way of the Angle Deep and No. 6 North Level, when he met some miners, who followed him to the fire.

Orders had been given to send down hose to connect with the seven-inch discharge from the lodgement nearby. The first lot was abandoned on the Angle Deep so that this connection was not made till the arrival of the second lot, by way of the South Deep.

Assisted by the air current the smoke quickly gathered in volume, and barred all entrance to the pit by way of the shaft. Mr. McKenzie, the Manager, who was immediately notified, was compelled to enter the Pit by the travelling slope, which is driven from the crop about 1,300 feet north of the shaft. He first reduced the speed of the fan. On the way down he gave orders to remove the horses, but all were suffocated before this could be done. As travelling by either of the North Deeps was impossible, he proceeded over the air crossing at the fan shaft bottom and through the fan shaft to the South Deep, and down the South Deep to the fire.

Timber and brattice were then put up across the main deep as the only possible means of excluding air from the fire.

The seven-inch discharge line from the lodgement nearby was broken, and after considerable delay in receiving the hose, two lines were connected to it. One was carried directly to the fire cross-cut, while the other worked through the first cross-cut above the fire in the Main North Deep.

By this time the Back Deep had already fallen, so that it was impossible to follow the fire through the cross-cut, where it had started, and the work of extinguishing was therefore practically confined to the Main Deep, which was not so badly fallen, and therefore more accessible. The opinion is that had the fire been confined to this deep alone it could have been extinguished with the water and hose available, but it was quickly travelling up the

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Back Deep and darting through the cross-cuts to the Main Deep, above the point where the men were stationed.

The morning of the fire it was difficult to persuade the men to work, as the conditions were very similar to those at Caledonia not long before, when a fire broke out in that Colliery. There an explosion occurred, causing the death of eleven men, including the Underground Manager, who had formed a party to locate it. In both cases the fire was near old and abandoned workings filled with damp. This made the men nervous and afraid for some time, but after the first day there was no difficulty in obtaining all the men required.

The Managers from the different collieries came and brought with them their subordinate officials and any men who had had experience with fire in a mine. These were organized in three shifts, of eight hours each, one of the Managers being in charge of each shift, with a mine official leading each gang. Each shift was composed of five gangs who fought the fire from different points.

The Fire Brigades from Glace Bay and Sydney composed some of these gangs, and brought with them all the available hose. Besides those fighting the fire, a gang on each shift moved coal cars, mining machines, mine tools, etc., from the pit. Another was kept busy sending down material, such as brattice cloth, timber, etc., while a third took charge of the ventilation, and was supposed to travel all the places clear of fire and smoke and to see that no gas accumulated in any part of the mines.

Two more lines of hose were now laid from the material shaft down the South Deep and across to the Middle Deep, one working from the top cross-cut, into the Main Deep, while the other was carried down to the next cross-cut in the middle deep. An ample supply of water was kept on these by means of two 500 gallon pumps, which were temporarily set up alongside of the railway by the dam and driven by steam from a locomotive standing on the track. Two lines of wrought iron pipe 5″ x 4″ respectively were laid from this point along the surface to the shaft where the hose was connected and dropped to the bottom. It was now impossible to ascertain the distance the fire had travelled towards the pit bottom on the Deep Back, as the only two cross-cuts available were those between the Middle and North Deeps, and these were being made use of to fight the fire on the Main Deep. Smoke barred all other passages to the Back Deep. This being the case, an attempt was made to reach a point 600′ above the fire cross-cut, on the Back Deep by following down the old horse road north of the Back Deep. After several attempts this point was reached, but the smoke was so thick and the heat so intense, that while only a short inspection could be made, it revealed the fact that the

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Back Deep had fallen in up to this point, although no fire was in sight. A line of hose which had to be carried along to this point was left open. The drain which carries some of the water from reserve through the rise workings of Dominion No. 1 amounting to from 500 to 1,000 gallons a minute was also diverted to this point and allowed to flow into the Back Deep.

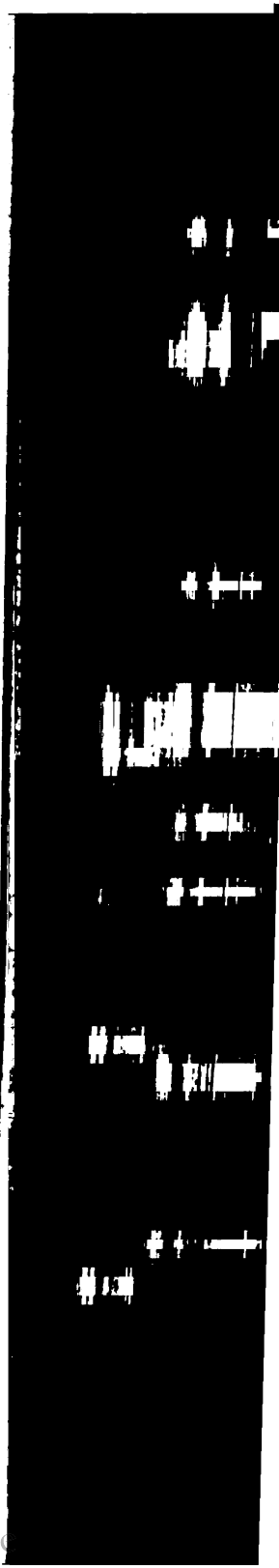
As, contrary to all expectations, the fire was not seen at this point, another attempt was made to reach it in this crushed district through room 30, which intersects the Back Deep a short distance above where the fire started. The object of this was to find out if the fire had worked its way through the stone stoppings which separate the back deep from the crushed and abandoned area, and also if possible to break through these stoppings and adopt the same method of fighting as on the Main Deep, namely before and behind. This method promised reasonable hope of success.

On the night of March the 23rd, 1903, after a very difficult and dangerous passage along room 30, a point was reached 750 feet from the Angle Deep and 200 feet from the Back Deep stopping, where it was discovered that the fire was making way into the old rooms. The necessary pipe had been laid down the Angle Deep and hose had been carried along to this point and was ready for use, but to attempt to extinguish the fire by this means in this old and abandoned section with its scores of openings, dangerous roof and stone filling was absolutely useless and a waste of time.

The work of fighting the fire from behind on the Main Deep and watching it at the first cross-cut from the Centre Deep was continued under the most disheartening circumstances, for the conditions were most unfavorable, as the section was the worst in the mine. The behaviour of the men was splendid, although they knew fire damp existed, and there was constant danger of an explosion; and in spite of smoke, heat, and falls of roof which drove them back time and again, they stuck to their posts till all hope of saving the mine was abandoned.

The fire was now travelling so rapidly, that fears were entertained for the safety of the shaft, the loss of which meant the loss of the pit. A careful survey was made of No. 4 North Landing to ascertain if it was possible to construct dams of sufficient strength to retain water in this section, but the pillars were so badly crushed and the roof so badly fallen that this was considered impossible, especially as time was of so much consequence.

The question of submerging the whole of the north side was abandoned for the same reasons. In the meantime two dams had been built across the roads connecting the North and South Deeps in order to protect and keep in operation the big 1,000 gallon



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pump, which took care of the water from the lower section of the pit. These withheld a considerable amount of water in the north side and kept the pump for the time being from being submerged by the water which was now entering the pit in considerable quantities through the hose and drainage from Reserve. In order to ascertain how far the fire had travelled up the Back Deep during this time, Mr. McKenzie and several others after several unsuccessful attempts, in which the lamps were extinguished by damp, finally succeeded in reaching through five feet of water a point 600 feet above the fire cross-cut, where it was discovered that the fire had passed this point, and was quickly approaching the shaft.

After this discovery on Saturday, March 28th, 1903, nine days after the fire started, complete submersion was decided upon. All the mining machines, with the exception of two, 280 pit tubs, all miners' tools, all horses, including the dead, were removed from the pit, together with parts of the electric locomotive. The mine was then sealed as closely as possible to prevent a supply of oxygen entering to the fire, but it had been worked in many places under a cover of only 100 to 200 feet, and the falls caused by drawing the pillars had extended to the surface, and thus made it impossible to exclude the air completely, even after taking all possible precaution. This was later proven by analysis of the gases taken after the mine was sealed. As can be seen from the results given below, the carbon dioxide was very much higher on April 30th, than on May 10th, which shows that the fire could not have been extinguished by the method of excluding the oxygen under existing conditions.

	CO_2	O.	N.	CO.
April 30th..	4.0	2.4	93.2	0.4
May 2nd	4.8	5.4	39.8	0
May 4th	5.2	3.6	90.8	.4
May 5th	5.4	4.0	90.4	.2
May 7th	4.4	6.8	88.8	.0
May 9th	2.4	10.6	87.0	.0
May 10th..	3.6	8.8	87.6	.0

No time was lost in turning on water from all the available sources of supply. Through an old room in the rise workings, a drain was driven through to the crop to catch the water of a small brook flowing by this room. One 1,000 gallon Northey pump and two portable boilers were set up on the shore of Lingan Bay, distant 800′ from the travelling slope. An 8″ pipe was laid between these boilers and the mouth of the slope. This water, together with that from the small brook, united with the drainage from Re-

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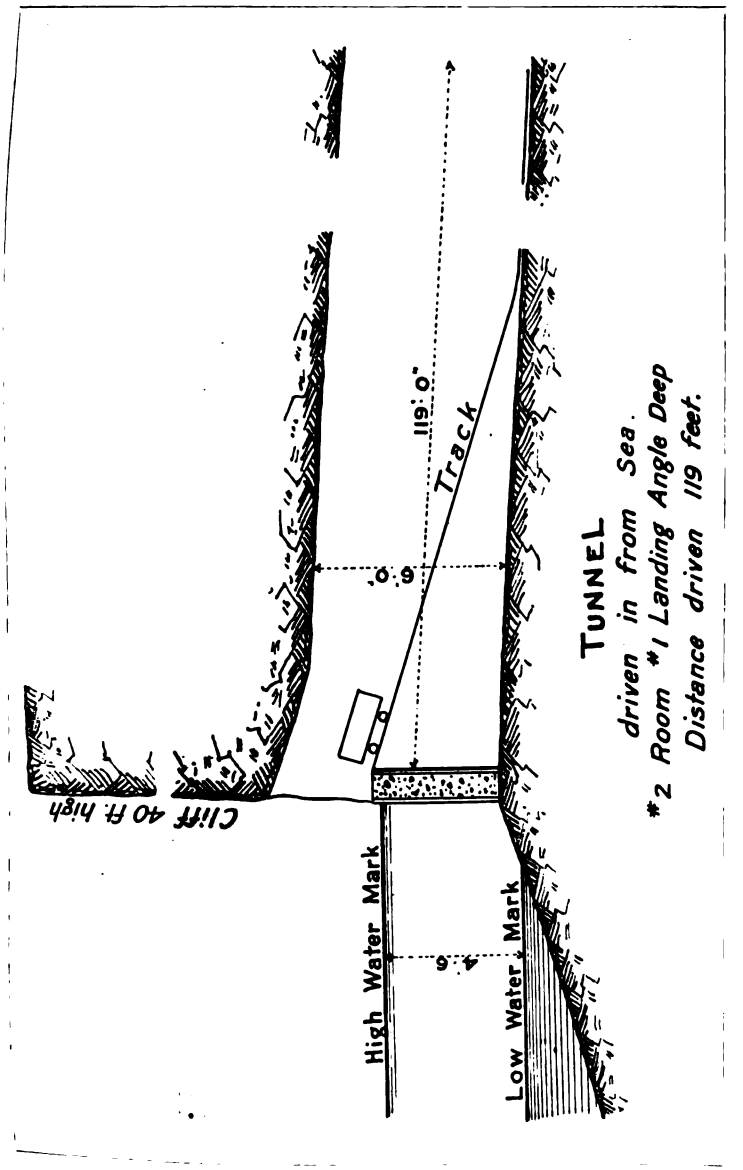

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serve, and flowed down the travelling road into the Back Deep 700′ above the fire cross-cut. This amounted to 1,350 gallons per minute, or in the fifty days from April 1st to May 20th, 97,000,000 gallons. It was estimated that 516,000,000 gallons were necessary to bring the water to a level that would cover the fire area, which now extended nearly to the shaft bottom.

To have filled the mine from this supply alone would have taken many months. To hasten the submersion, it was decided to call into requisition the waters of the Atlantic. A tunnel 119′ long 6′ high 6′ wide was driven in from the shore to the nearest room, which was Number 2 room, Number 1 landing on the Angle Deep. This was driven in four days, or an average of 30′ per day by machine cut, for which an air line had been laid along the surface from the compressor house. The coal was loaded in a tub placed on the track laid for the purpose, and hauled out to the shore by hand. While the work was in progress a temporary dam was constructed across the opening, in order to seal off the pit at high tide, when it would otherwise have filled the tunnel, and delayed the work. This was composed of two walls of three inch plank separated by an eight inch space, which was filled with concrete. A sliding door four feet by four feet located above high tide, afforded a means of entrance and exit to and from the tunnel. Beneath this, after completion, another door four feet by four feet was cut and used as a means of regulating the flow of water into the pit. The sea was first let in on April 7th and finally closed on May 23rd—a period of 46 days—but the flow of water was not continuous. The actual time of flow in this period amounted to fifteen days, during which it is estimated that 420,000,000 gallons entered the pit at a rate of 28.000,000 gallons every 24 hours. 96,000,000 gallons entered by the other means mentioned, which totals 516,000.000 gallons. This brought the water level with the bottom of the shaft.

After the pit was submerged the opening was stopped by a permanent dam, which consisted of 92 pieces of spruce and hemlock 10 inches by 10 inches at one end, and eight inches by ten inches at the other end, each piece being faced on two sides with one inch pine boards. Its thickness was about seven feet. Through the lower portions of this dam a 17″ diameter pipe was laid with a plug at the lower end, which was forced into the pipe by the pressure of the sea when the flooding was completed.

Readings of the rise of water in the pit were taken by means of a float and wire dropped down the borehole to the face of the South Deep. The waters of the sea were shut off from time to time on the assumption that large quantities were withheld in the upper workings by falls and other obstructions, as the bore hole

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readings showed that water raised the level at the bore hole for several days after the sea tunnel was closed.

Another source of anxiety and cause of delay in flooding was the question of the strength of Reserve Barrier. Below No. 5 South Level of Dominion this was sufficiently thick to withstand the pressure brought to bear on it, but above that point or from the bottom of Reserve Main Deep the surveys showed varying thicknesses. The water from the Main and French slopes of Reserve flowed through a borehole driven through the barrier at a point in the face of No. 3 South Landing of Dominion, and here the thickness was 53 feet. The face of the Reserve Main slope is 198 feet below sea level, which when the water was on a level with the bottom of the shaft was under a level of 130 feet, or 57.2 pounds per square inch, which equals 4.1 tons per square foot. To guard against any possibility of accident through the failure of the barrier, and in order to protect the workings of Reserve other than those of the main slope, two dams consisting of 10" x 10" spruce and hemlock laid in two walls with four feet of concrete between were built across the narrow places of No. 10 Landing, which was the only connection between the main slope and the rest of Reserve. The barrier however proved effective. The water worked through the strata and came in in considerable quantities through the roof between No. 9 and No. 11 landings, but outside of heavy condensation on the face of the barrier no other noticeable features developed.

The filling continued as above described until the readings taken at the borehole indicated that the water had reached the bottom of the shaft, but a float lowered into the shaft showed that the water had not reached this point. A close examination of the borehole was then made, and it was found that water bailed out by a bucket lowered the water about 25 feet, showing that the readings taken were not a true indication of the rise of the water in the pit. This method was therefore of no value, and, without any other gauge, the regulation of the flow of water became a matter of judgment.

On April 30th, 21 days after the mine had been first sealed, steam in place of smoke began to issue from the test holes in the shaft, proving that the water instead of being on a level with the bottom had apparently only reached the fire territory. An additional 250,000,000 gallons was therefore necessary to cover this.

Great care was taken to keep the water from actually covering the shaft bottom, as a rise above that point would entail much extra labor and loss of time in pumping out, for then the pumping would have to be started by way of the travelling road and by placing some pumps in the shaft. To provide for this

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emergency an air line was laid from the compressor house to the mouth of the slope but there was no necessity to make use of it.

On May 11th the pit was opened, and the fan started, but smoke made its appearance. The pit was again closed, more water was let in, and again opened on the 23rd May, when no smoke was found. On May 23rd a small hatch 7″ x 9″ was opened in the coal shaft, and at the same time a trap-door was opened in the tunnel at the shore. The air therefore travelled from the trap door at the shore across the fire district and up the coal shaft.

Parties were organized for searching, underground relief, and superintending operations on the surface, The underground party entered the pit by the travelling slope. Considerable damp was met with, but great care was taken, and no accidents happened. The temperature reached 114°.

Another party which entered the pit by the tunnel at the shore was once driven back by damp, but next day succeeded in connecting with the party on the travelling slope.

On May 24th 7.30 p.m., the fan was started exhausting, and the main shaft was uncovered. From this time the work of opening up and arranging for pumping out the pit was vigorously carried out. The water had risen to the shaft bottom, but the pump, although partly covered, was started on May 30th, 1903.

One of the greatest mine pumping propositions was now before the Dominion Coal Co. Time was of great consequence on account of the demand for coal. The total quantity of water required to be pumped amounted to approximately 516,000,000 gallons, besides what the mine made through feeders and falls amounting to 500 gallons per minute. When it was decided to flood the pit, telegraph enquiries had been sent to all pump makers for prices and sizes of pumps on hand for immediate delivery, and it was a case of taking almost anything that could be immediately shipped, and the material and machinery bought for this purpose consisted of the following pumps:—12 Knowles Duplex 14x 18½ x 10—500 gallons; 4 Smith Vaile Duplex, 14 x 9 x 12—600 gallons; 4 Jeansville 12 x 8 x 18—600 gallons; and two Worthington, 14 x 12 x 10 Duplex—1,000 gallons; making a total number of 22 pumps of a total capacity of 12,800 gallons per minute. The pipe amounted to 27,000′ of 8″, 24,000′ of 6″, 900′ of 12″, 900′ of 10″ and 26,000′ ranging from 5 to 2½ inches.

On the two South Deeps 8 pumps were worked, which discharged to the surface through four 8 inch pipes. They were arranged in sets of four on each deep, two pumps connecting to one 8 inch discharge.

These sets were staggered and moved down the deeps when-

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ever the suction reached a length of 350 feet. The North Deeps down to the fire were so badly fallen that pumping could not be continued in them. Four pumps were therefore carried down the Angle Deep and discharged up the shaft to the surface till No. 1 Landing was reached when discharge lines were laid along this to the tunnel opening to the sea, thus cutting off 80 feet of head. The pumps on this deep were carried along on a suction of about 450 feet until No. 4 Level was reached, when they were moved over to the Centre and North Deeps, discharging to the sea through four 8 inch discharge lines.

When the water receded below the lodgement on the North Deep this lodgement was used as a second lift. Five pumps were placed at this point, and water was delivered to them by the four working down the Middle and North Deeps. The eight pumps working on the South Deeps were then pumping to the pit bottom lodgement from which four large pumps pumped to the surface through the material shaft. The pumping was of necessity at times very slow on account of the numerous falls which had taken place by the shifting of pumps and by the resumption of mining before the pit was clear of water.

On May 30, 1904, just one year after the beginning of pumping operations, the mine was completely pumped out. Besides the 516,000,000 gallons which filled the mine, the mine was making about 500 gallons per minute during this period, which amounted to approximately 276,000,000 gallons. The total number of gallons pumped was therefore 792,000,000.

Not taking into account the work done by the pumps at the second lift, the performance of the pumps was as follows:—

Knowles	47,846 hours.
Smith Vale	9,640 "
Cameron	111 "

The results show that the Knowles and Smith Vaile and Cameron pumps worked constantly during this period at an average of 50% of their capacity or at the rate of 250 gallons per minute, or 15,000 gallons per hour of the Knowles and Smith Vale, and 12,000 gallons per hour for the Cameron.

The Air Compressors which kept these pumps in operation were worked to their full capacity. To relieve them the pumps located around the lodgement at the shaft bottom were driven by steam.

The action of the gases from the fire on the pipes, ropes and iron work around and in the coal shaft was very destructive. All the rope and pipe that had been exposed to it were so badly eaten that complete renewals were necessary.

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In the fire section of the mine both deeps on the north side had fallen completely to a height in some places of 12 and 15 feet, as shown by the crossed shading in plan. In very few places was it possible to crawl over these falls. This necessitated much labor and expense in cleaning, tunneling and timbering to place the travelling road and haulage way in a fit condition for operation. Even if it had been possible to do without the use of these roads, the shale and roof coal were found to give off a certain amount of heat, on the haulage road particularly. For this reason it was considered better to clear it out than to run the risk of the fire starting again on this deep. There was no apparent reason why the temperature of this material should have been so much higher than at any other place to which there was access, unless the dust, which was very fine, combined with oil dropped from the pit tub axles, made the condition more favorable for spontaneous combustion, and with the enormous weight of the roof that had fallen, pressing upon it, excluding the air current.

The stone removed from the falls amounted in round numbers to 25,000 tons, and was removed from the pit. This does not include about an equal quantity which was removed from falls when reaching the working face, as this was stowed in the mine.

The places where these falls had taken place were newly-timbered. About 3,000 booms were put in besides props, etc., used for lofting. In some places where the roof was very heavy props were used in the centre of the boom, but generally the booms were placed in the rib or pillar and required no prop. Props were, of course used and lagged behind where the pillar was crushed.

No harm was done to the shaft, but around the shaft bottom, as shown on the plan by parallel shading, the action of the heat on the roof made it necessary to bring it down to a height of two feet, which greatly improved the condition of the roads about the place.

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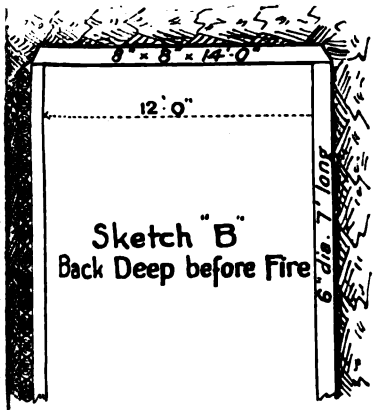

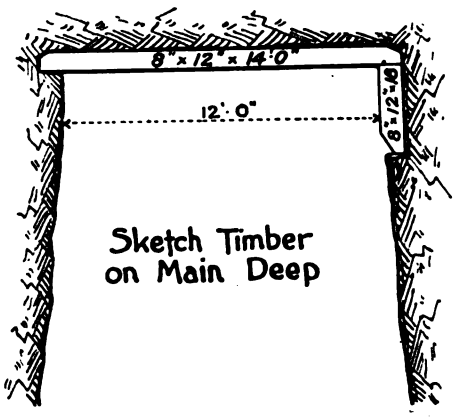

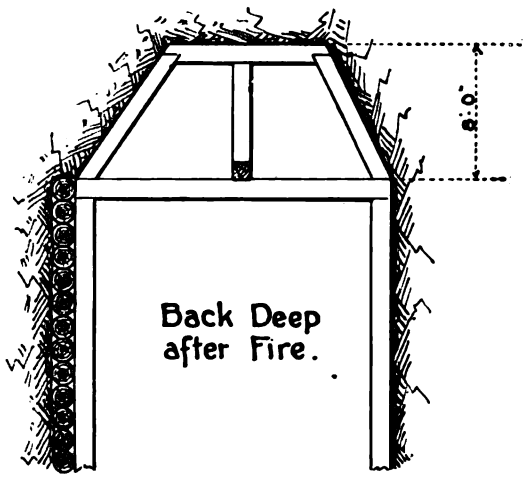

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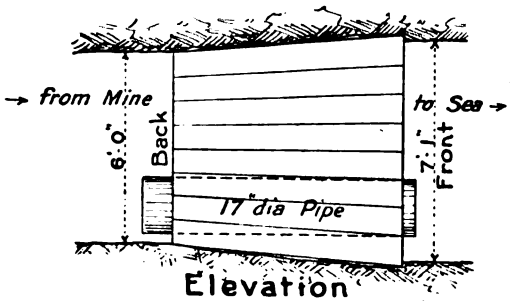
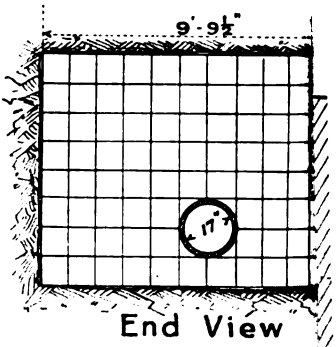
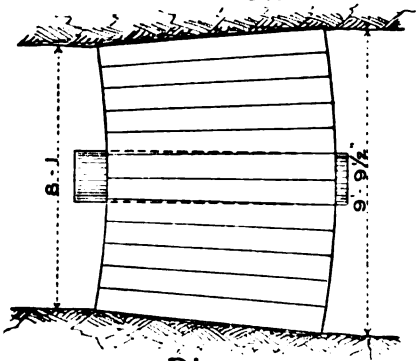


Elevation



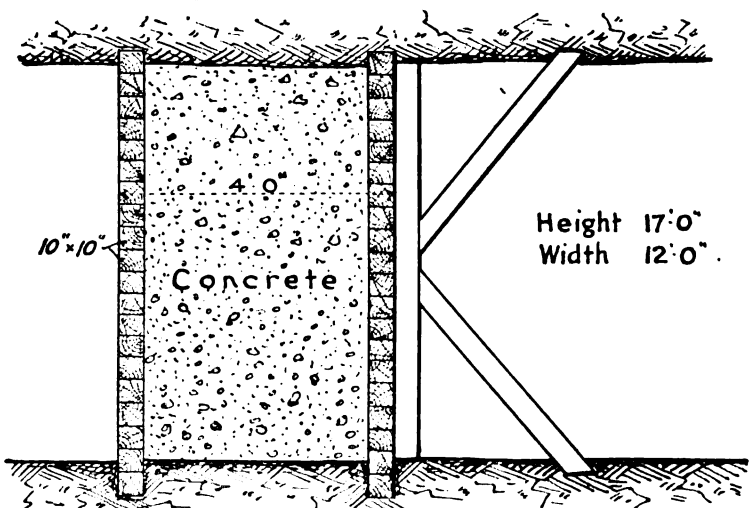
End View



Plan

FRAME DAM

built in Tunnel connecti
Mine with Sea
made up of 92 pieces spr
& hemlock 10"×10" at large e



WOOD & CONCRETE DAMS

On Level connecting Main and French Slopes of Reserve.

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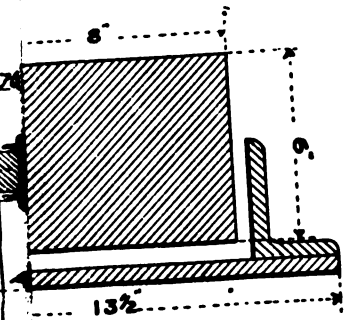

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THE MINE FIRE
AT
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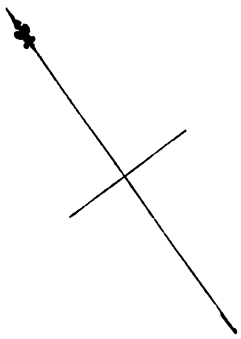
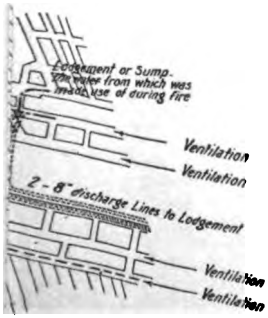
MAP
OF THE PART OF THE
AFFECTED BY THE FIRE

Scale of Feet





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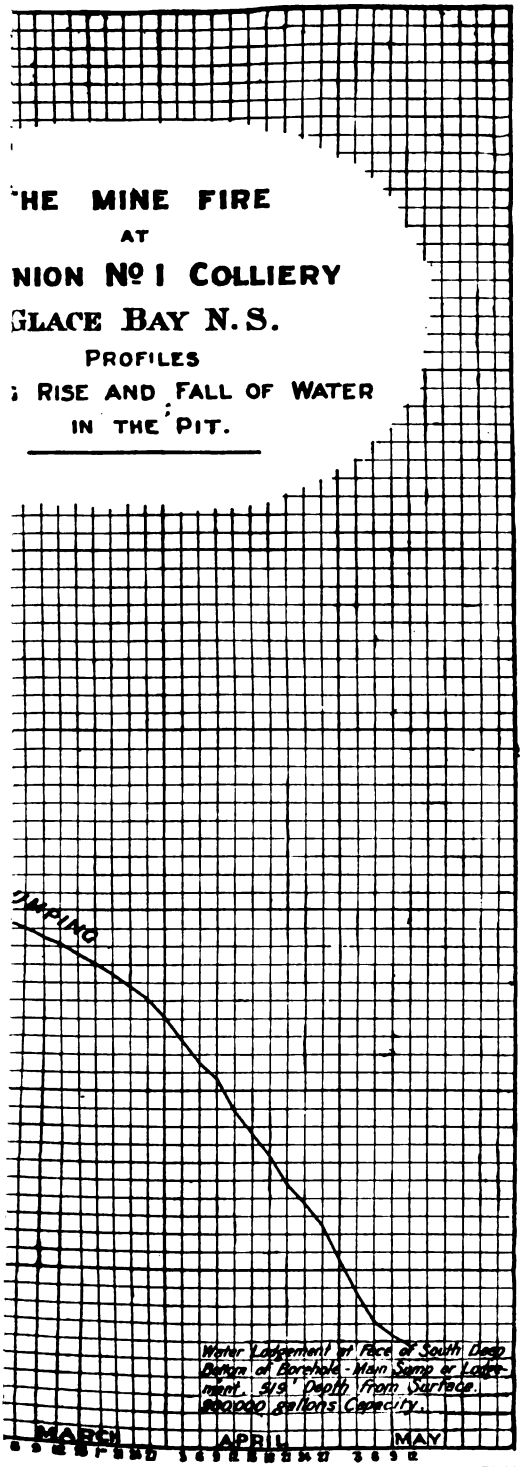

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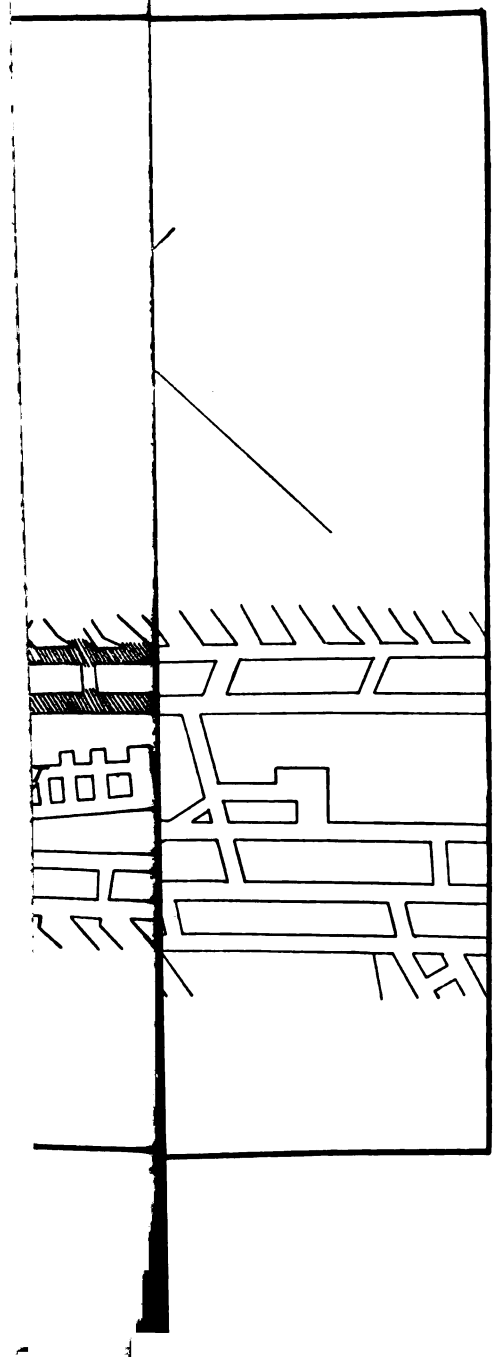
TRANSACTIONS CAN. SOC. C. E.
VOL. XIX. PLATE 11.



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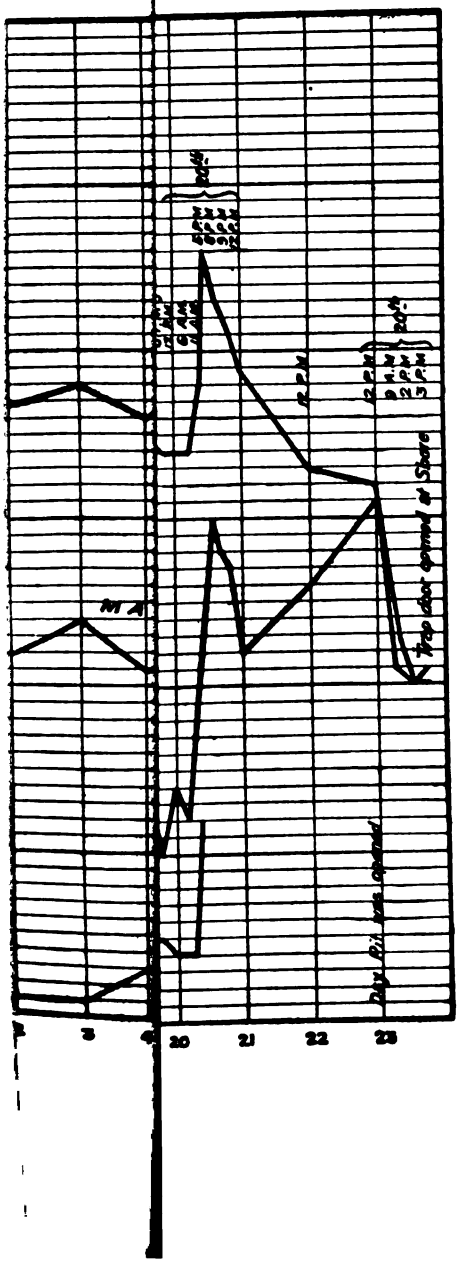

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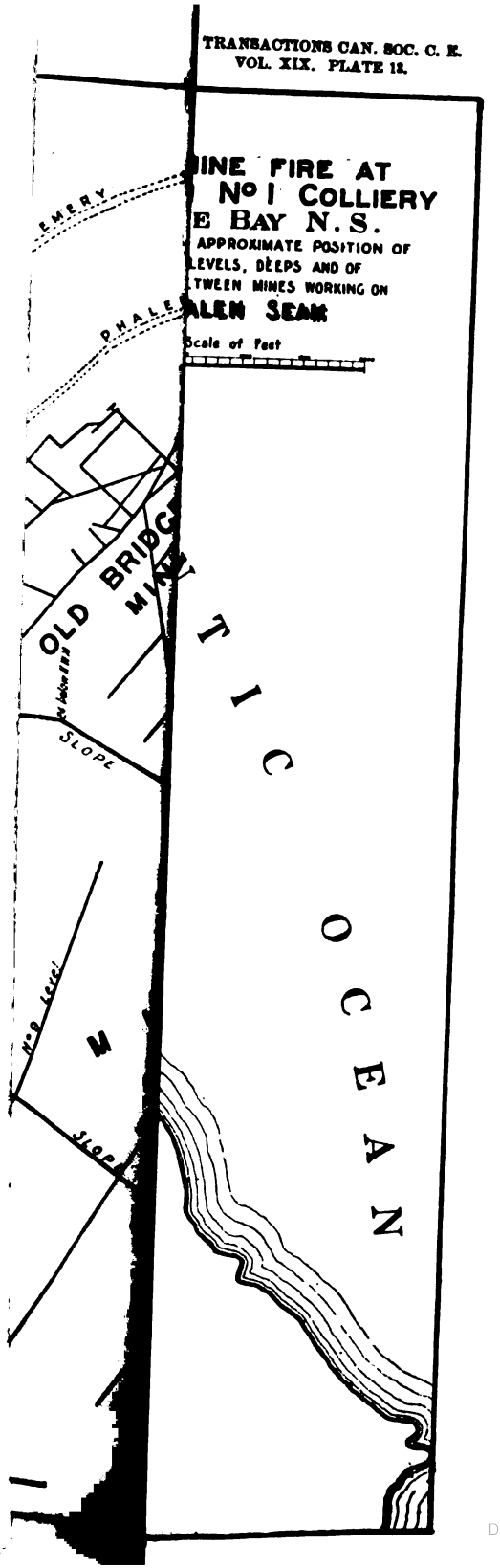

Ir. Hardman.

Ir. Stairs.

Prof. Porter.

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DISCUSSION.

Mr. J. E. Hardman said that if the authors of the paper were present it would be interesting to bring up several points in discussion, but in their absence, he felt a delicacy in doing so. He might say, however, that he could not see why it had taken the colliery managers nine days to decide to submerge the mine. Mr. Hardman.

Mr. E. G. Stairs replied that he believed one reason was that there was a great deal of slack coal in the neighborhood of the fire, and the map showed that in the immediate neighborhood there were crushed pillars. Probably the fire remained in this place for a long time, and did not look as bad as it really was, and thus encouraged the management in their hope that the fire was not serious. Mr. Stairs.

Prof. Porter said that there was nothing in the paper or correspondence which touched directly upon the point brought up by Mr. Hardman, but on one of the maps there was a small area marked: "The fire was confined to this place for several days." Prof. Porter.

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GENERAL SECTION.

President—D. MACPHERSON.
Vice-President—C. H. KEEFER.

A meeting was held Thursday, February 23rd, 1905, Mr. Duncan MacPherson in the chair. The following paper was read by the author:—

PAPER No. 224.

PORT COLBORNE HARBOUR WORKS.

Description of Design, Methods and Plant.

By J. M. HOGAN, S. Can. Soc. C. E.

Port Colborne, situated at the southern or Lake Erie end of the Welland Canal, marks the limit of clear lake navigation, for from this point to Montreal the draft of vessels is controlled directly by the legal allowable draft of canals, which for the Welland Canal is 15′ 6″.

The Canadian Government has, since 1900, been engaged in extensive harbour improvements with a view to making Port Colborne a transhipping point of large dimension and a rival, if possible, to Buffalo. Should the Port Colborne scheme work out as intended, the navigation of the canal system would be largely augmented where at present, despite free tolls, it is very small, especially considering the facilities offered and the excellent design of the canals.

Much of the grain which at present goes to Buffalo in the large lake carriers and thence to New York by rail or Erie Canal might be diverted to the St. Lawrence route were proper facilities provided at Port Colborne for transhipment, and it was to provide just such facilities that the works were undertaken.

Fear of such a diversion of trade doubtless is the prime cause of the proposed large expenditure of $100,000,000 by the State of New York in deepening the Erie Canal; but even in its improved state the Erie Canal route will be inferior, both as regards depth (10′ as compared to 14′) and distance, for the St. Lawrence route (Port Colborne to Montreal) is shorter by over 120 miles than the Buffalo to New York waterway.

The works comprise new docks, excavation of channels, and two large breakwaters to east and west of the port. These break-

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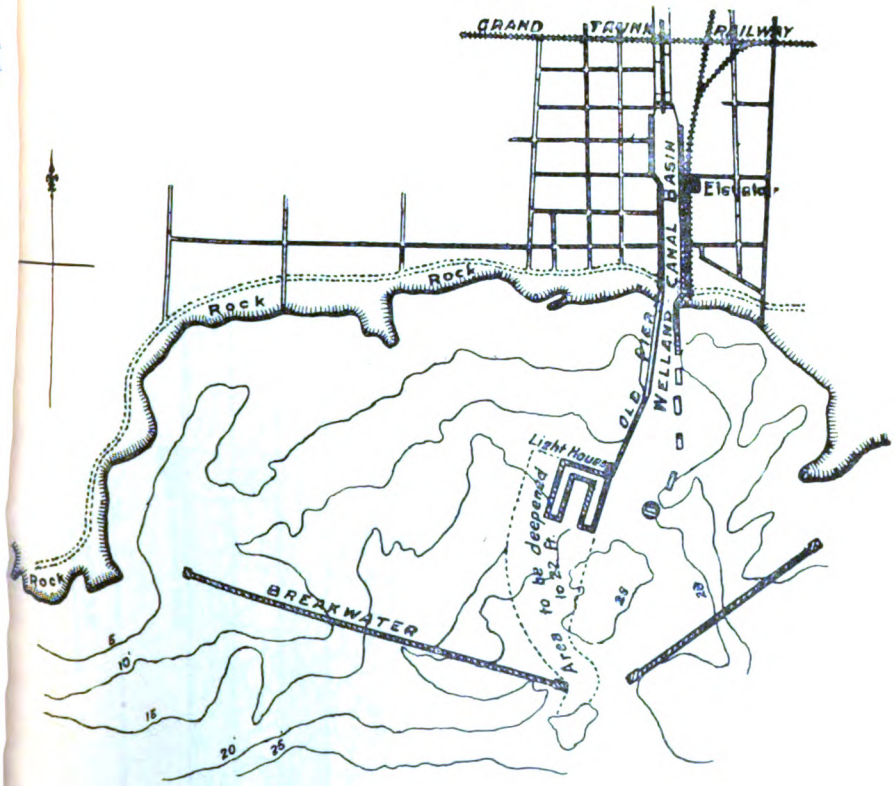
waters, of which one, 5,000′ long, is finished, while the other, 2,400 long, is half completed, are under the supervision of Department of Public Works. The rest of the works are controlled by the Department of Railways and Canals. This paper will discuss only the latter.

The work may be divided into excavation of channels and



PORT COLBORNE HARBOUR IMPROVEMENTS

Fig. 1.

the providing of new docks. Beginning at the breakwater, a depth of 22′ is to be made to the north end of the canal basin and in the vicinity of the two new docks built at the end of the old pier. All of this excavation up to the entrance of the canal basin is in solid

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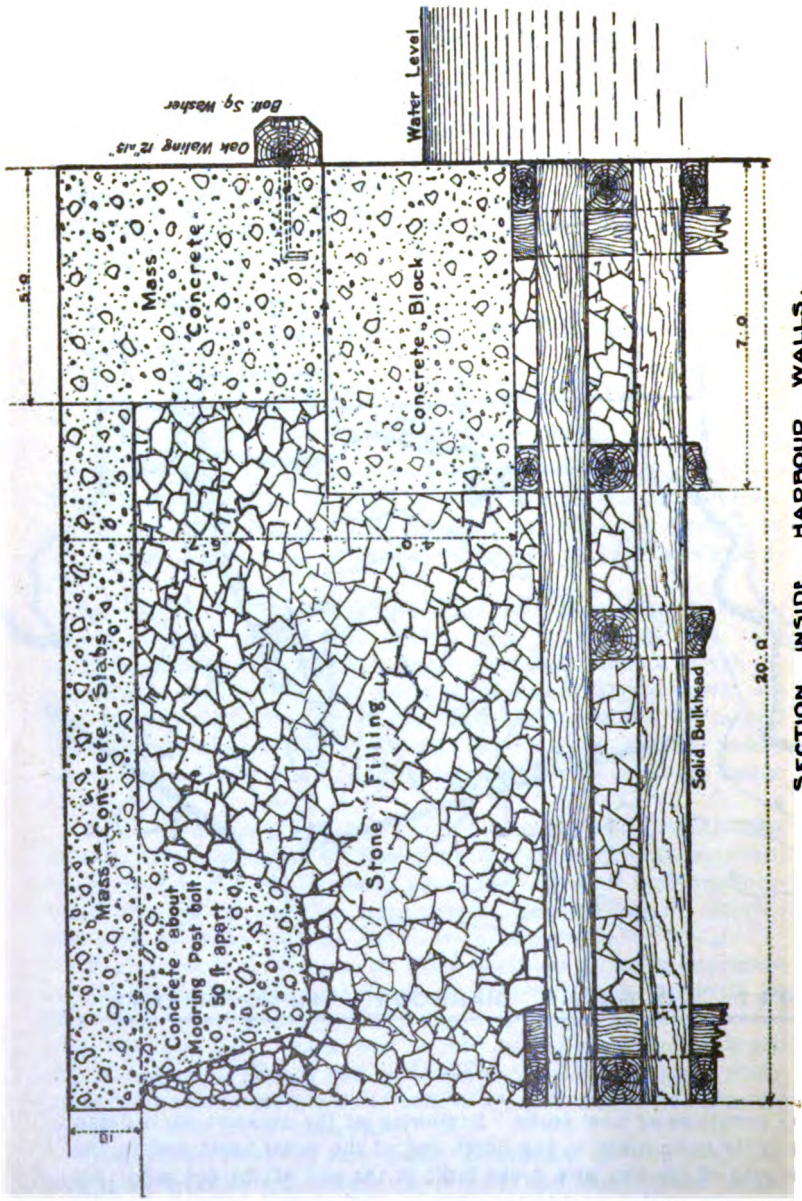

SECTION INSIDE HARBOUR WALLS.

Fig. 2.

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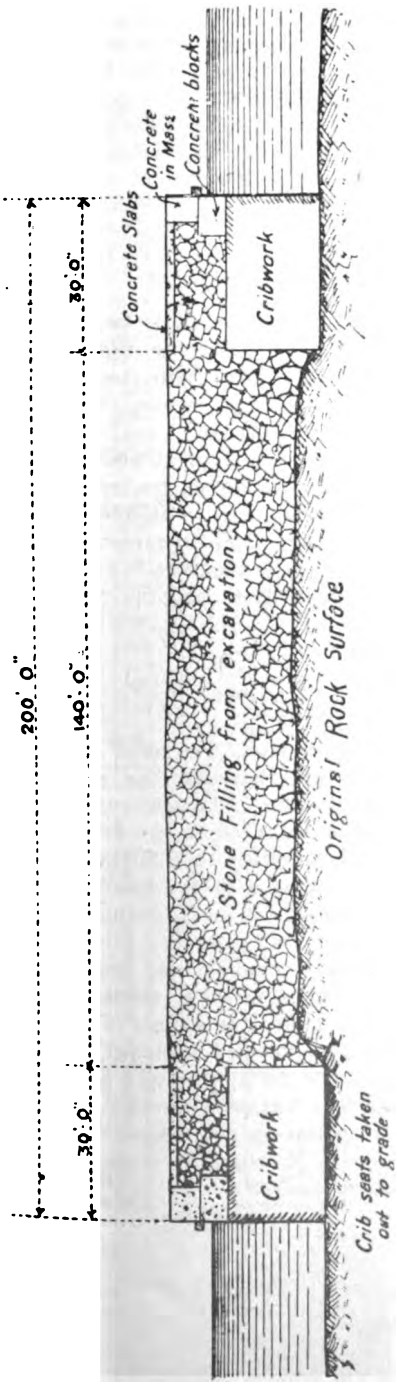

SECTION THROUGH PIER".

Fig. 3.

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rock, over 300,000 cubic yards in all, averaging a cut of 3 to 4 feet over its area. The limit of deepening to allow of approach to the new outside docks is shown on the plan (Fig. 1).

These new docks, which are 700′ x 200′, together with the new docking provided along the sides of the canal basin itself will give in all about 1½ miles of concrete docks, allowing of approach by vessls up to 22′ draft. On one of the outside docks is to be placed an elevator for transhipment of grain.

Dock Design.

Design of inside and outside harbour docks is similar save for width of crib. Figures 2 and 3 show the design which is essentially submerged crib work filled with stone, and surmounted by concrete blocks carrying a mass concrete wall, the whole covered for width of crib by an 18″ slab of concrete.

These cribs are built to within 2′ of an assumed water surface (14′ above mitre sill of lock) so that no timber is exposed to rot. The use of concrete blocks does away with the difficult operation of placing green concrete under water, and ensures a lasting job in a position where permanency is required. Crib seats were in all cases dug out to grade with dredges, but the interiors of outer docks were left as found.

Cribwork.

Plan "C" shews details of cribs. The outer harbour cribs were 30′ wide as against 20′ for inner harbour, the extra width being called for by the exposed position. The construction points do not vary beyond the extra solid bulkhead in the 30′ crib.

The timber used, about 35,000,000 ft. B.M. in all, was all 12″ x 12″ square hemlock, proud edged with the small quantity of wane allowed in ties or longitudinals. A small quantity of 6″ x 12″ is used for bottom grillage and block seat.

Ties and longitudinals are dovetailed, as per sketch. They are placed at intervals of 10′, except in lower course, where an extra tie is put in every 5′. Side joints are simply butted, ends being cut exactly square with ¼″ allowable opening. End joints lap alternately. The longitudinals form two solid bulkheads for full length of the crib, which is a feature of great strength. This calls for short 10′ fillers between ties on every second course.

Binders are placed every 20′ with the object of tying the face courses together vertically.

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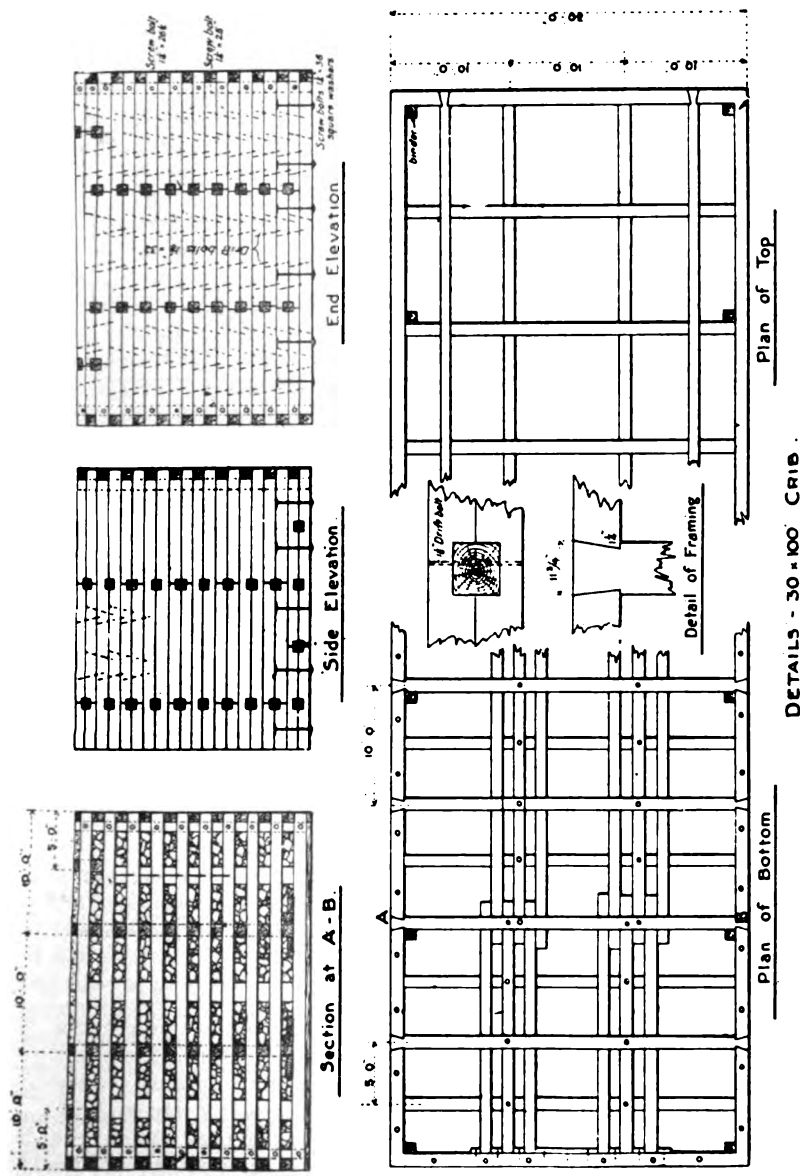

Fig. 4.

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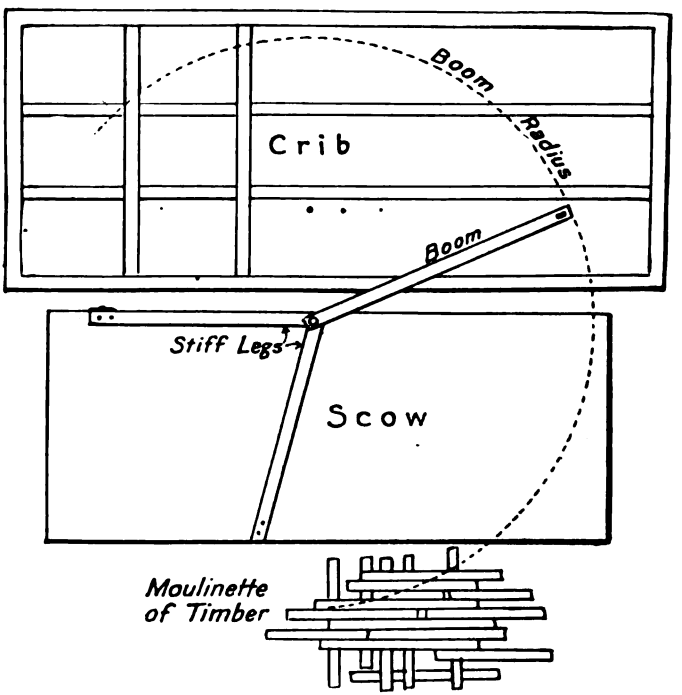
BOLTING, ETC.

Binders are fastened to face timbers and ties by 1¼" x 26" screw bolts with square plate washers.

The three lower courses of crib are made specially strong to withstand stresses caused by filling, weight of wall, contact with uneven bottom, and rough usage in handling &c. They are fast-



METHOD OF BUILDING CRIBS BY SCOW.

Fig. 5.

ened with 1¼" x 36" screw bolts and washers passing through the whole three courses and spaced 5' apart. The other courses are bolted as shewn with 1⅛" x 32" drift bolts having sheared points. These bolts pass through two entire courses and partly into a third.

The short blocks shown in section, coming almost under the rear of concrete block, aid in preventing any deformation of tie and consequent settling of wall.

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These cribs are built on ways up to 7 or 8 courses, and then launched and finished in the water. Owing to depth of water in the basin being insufficient to float a finished 20 course crib, it was necessary to tow cribs into the open lake, and finish them near their sites.

Cribs were built by derricks afloat on scows. A feature was the placing of the derrick at the edge of the scow, and so arranging the stiff legs that the derrick boom could have greatest possible radius of action. Only one move was required by the scow to lay a whole course of timber. Hoisting engines having boom fall and swinging drums were used, so that the engineman controlled the whole movement of a stick of timber. The timber was unloaded from vessels directly into the water in piles or moulinettes; this being the most convenient method of storing the enormous quantities of timber used. As required, the moulinettes were towed alongside the crib scows and built directly into the cribs. The timber was thus placed in the crib with only one handling, as the ship was bound by contract to unload its own cargo.

The crib scow also had an air compressor plant to supply pneumatic augers used for boring, as all drift bolts were driven into holes bored $\frac{1}{8}$ to $\frac{1}{16}$ too small.

A gang of 20 men in all launched two crib bottoms of 7 courses and binders regularly each week, while a completed crib represented about 8 days' work.

Cribs were sunk by placing on them several concrete blocks on temporary platforms at ends and middle. When properly aligned and level the filling was dumped in as rapidly as possible, and blocks later placed in their proper position. Owing to weather conditions the filling of each crib had to be completed at once, or about 2,000 cubic yards of stone filling provided. All this filling was dredged up from the excavation referred to.

Concrete Blocks.

These blocks, 4′ x 4½′ x 7′, were moulded in timber forms made of 2″ dressed pine, tongued and grooved. A piece nailed to the side of mould gave the reguired joggle to the block. The moulds were tied across by two ½″ round iron rods with nuts, threaded both ends. The lower rod passed through the partition forming end mould of block.

Sides were held in position by the shoulder formed by lapping on 3″ x 4″ upright. To remove moulds, nuts are slacked and uprights taken down, when the sides will remove in one piece and may be utilized again. These moulds were filled with concrete in layers and allowed to set for 48 hours before removal of moulds.

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After five days these blocks were sufficiently set to be removed by derrick.

In top of the block is a basin-like depression, while in the side a slot or joggle is moulded. When blocks are placed side by side, the mass concrete of wall filling up joggles, etc., forms a strong joint between each block and between top of block and wall above, and prevents any lateral displacement of blocks relative to the wall which might be caused by impact of the heavy seas or vessels.

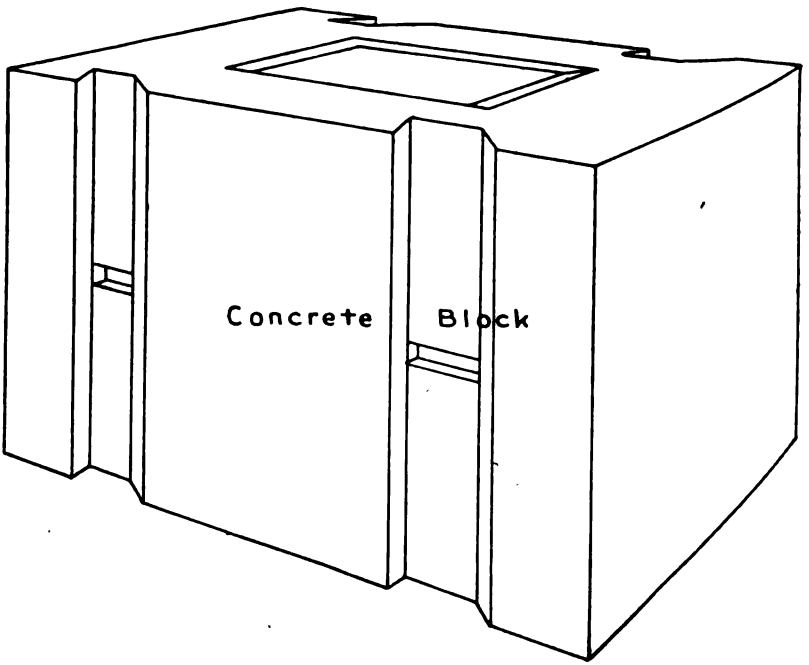

Fig. 6.

The joggle also allows of the simple method of handling the blocks shewn in Figure 4.

Much difficulty was experienced in setting these blocks level and close jointed, especially the latter. This was due to the uneven character of the bed left by the dumping in of stone filling and the difficulty of levelling same in 2′ and 3′ of water. As an aid to obtaining close joints the blocks are now made with a batter of 2″ from face to rear of block which allows of the front face being brought closer to the neighbouring block.

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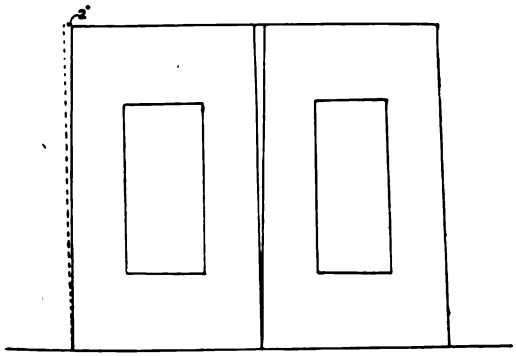
Moulds for the concrete wall are of similar material to block moulds and similarly fastened, except the lower rod, which rests on the block and supports outside upright which overhangs the face of wall. This rod remains in the wall. The rear upright is wedged into the joggle. Moulds were erected in sections of 60 to 75 feet, a day's work. The next day's work began at finishing point of previous day, which allowed sufficient expansion. Canvas nailed to inside face of mould and allowed to drape over the block, was extensively used to prevent washing out of concrete by seas before thoroughly set at the level of block.



SHOWING BATTER OF BLOCKS.

Fig. 7.

CONCRETE.

Concrete was 1. 2. 4. mixture. Owing to the large area covered by the works it was impossible to set up a permanent plant anywhere. The convenient approaches to most of the work being by water, the plan of utilizing a floating plant was adopted with good results.

A large deck scow was equipped with a derrick, mixer, and crusher, and storage provided for cement and sand. The lay-out was so arranged that the derrick, having 68′ boom, controlled all the operations. Materials for the day's work were loaded each morning, and the scow towed to the site. The stone for crushing was obtained directly from the back filling of the cribs and hoisted to the crusher platform in tubs, where two men fed it continually to the crusher. This stone, being dredged from the bottom of the lake, was clean and excellent for concrete. The stone thus crushed runs out below into another skip or tub. When 3″ or 4″ have accumulated the spout door is closed and a wheelbarrow of sand from

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the pile close at hand is dumped in and spread, followed by two or three bags of cement. This alternate process is continued until the box is filled, when it is hoisted up and dumped into the incline bin of the mixer, and thus runs in a continuous stream through the mixer itself and into moulds below. Besides being continuous, this system is compact. Where stone was not available from the filling it was brought alongside in scows and used as wanted.

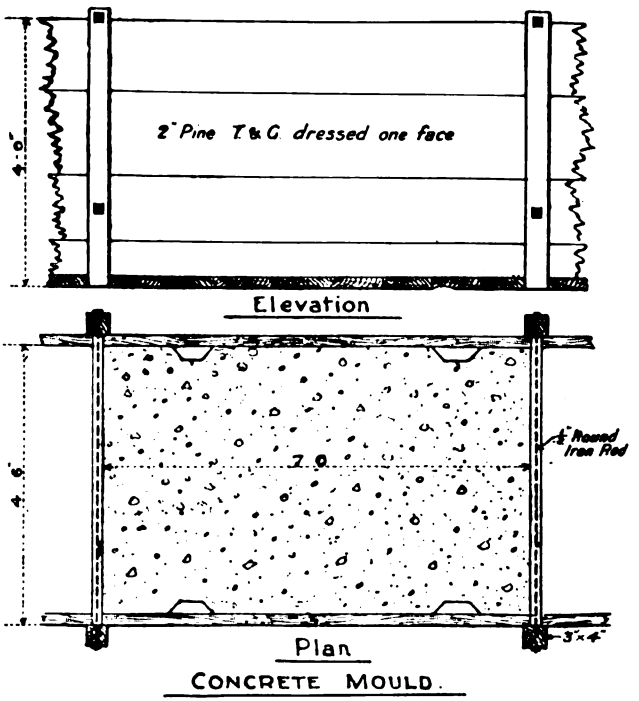

Fig. 8.

The mixer used consists essentially of a sheet iron spout having small iron rods placed perpendicular to line of flow to give a tumbling or turning over motion to the concrete. A perforated pipe, controlled by a valve sprays water over the dry mixture as it passes. A door at the bottom of spout is operated by a man, who also controls the water. The door is kept closed till the lower chamber of the spout is filled, when the concrete is released and the door closed for another batch, or about two shovelfulls.

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A larger boiler on the scow provided steam for hoist, crusher and engine, and small pump, which fed water to the mixer.

An average day's work consisted of 65 to 75 yards for a gang

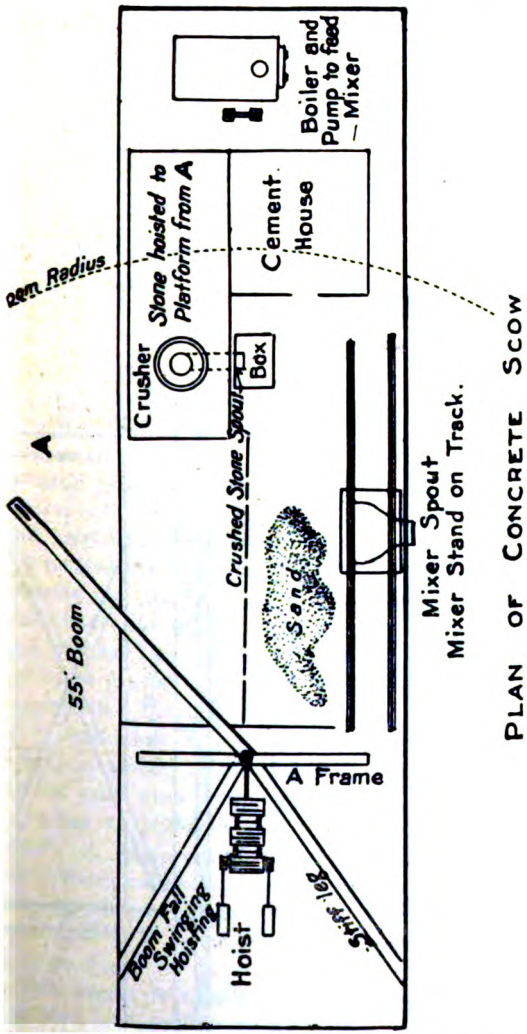

Fig. 9.

of 18 Italians, forman and hoistman, or about 50 cents per yard for labour. Cement used (at least 40,000 barrels to date) was Rathbun "Star," made in Deseronto, Ontario, and the results obtained have been excellent.

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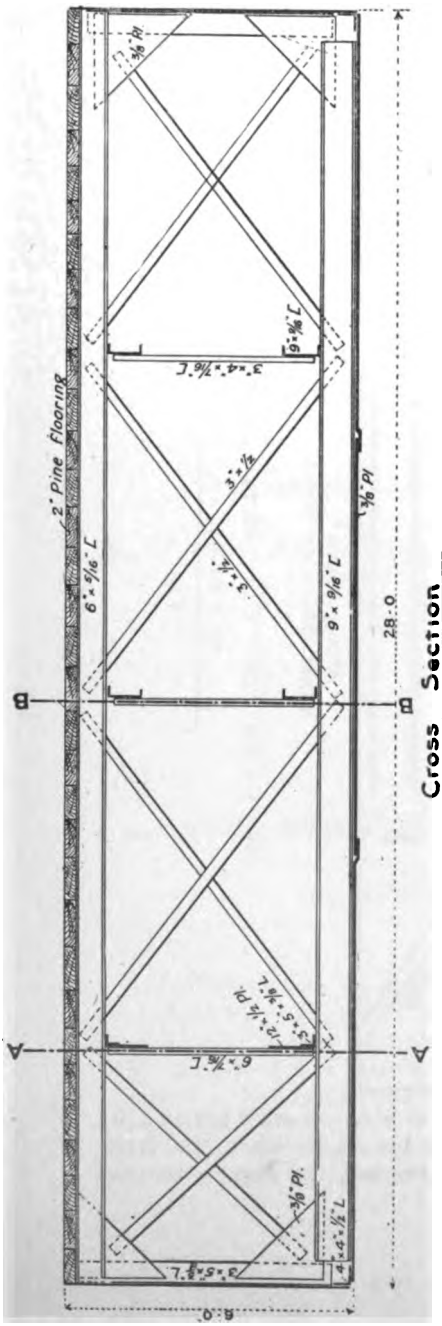
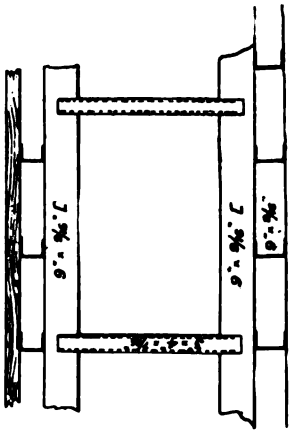
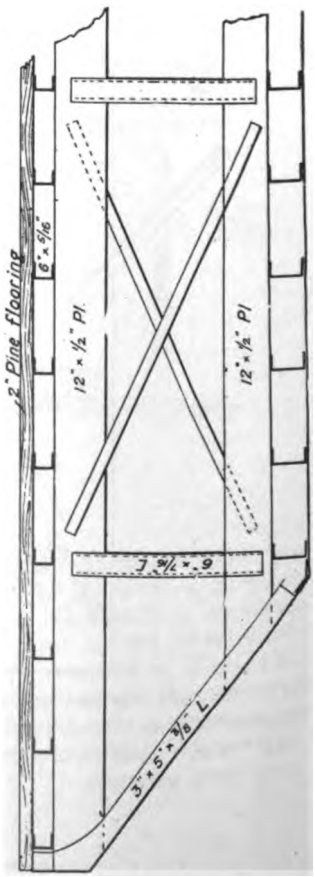


Cross Section

DRILL BOAT "VOLCANIC"



Section B-B



Section A-A.

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The mixer moved on tracks, and both could be lifted off and set up on a wall within radius of boom, and the concrete process go on as before. Such a method was used in laying the concrete slab covering of the docks.

Excavation.

The principal item of this part of the work consisted of the drilling, blasting and dredging of 300,000 cubic yards of very hard flinty limestone over a great area. The above quantity is in place, not scow measurement. The cut varied from 6″ to 6′ but to get down to grade it was necessary to drill and blast to 2′ or 3′ below the grade line to avoid pinnacles and ledges being left. No payment is allowed, however, for this extra depth. Owing to constant interruptions by storms this has been the most troublesome part of the work.

Drilling and Blasting.

To drill and blast, a submarine drill boat is used, consisting of a specially strong hull, steel preferably, housed over and carrying the boiler, large steam pump drill frames, drills and hydraulic feed for same.

The latest type used at Port Colborne, and built in 1903, consists of steel hull 100′ x 27′ x 6′ of ⅜″ plate (see Figure 10) having cross and longitudinal trusses composed of channels and bracing. It will be noticed that the drill frame side is specially strengthened by shortening the panel length in cross section so that the panel post comes under the drill frame, and also by the use of ½″ x 12″ plate and bracing longitudinally. The stresses are here a maximum, owing to constant pounding of drills and the impact of the blast underneath. The boat is pinned up, i.e., part of her weight, possibly 60 tons, taken on oak spuds 14″ x 16″ at each corner. She is thus held in place. These spuds run in guides and have cast iron racking sunk even with their face on inner side. A gear wheel attached to slides works in this racking and lowers or hoists spuds. A single upright engine operates a series of shafting under deck which connects by a sprocket wheel and chain to the gear wheel working in the racking. This method of pinning up is considered preferable to an engine on each spud where winter work is to be done.

The drill proper is attached to a carriage composed of two angles latticed, and having a saddle at the top. This carriage moves on two uprights, i.e., the drill frame. An hydraulic ram, working between these uprights and attached to the saddle takes the place of the hand feed on land drills. This ram is controlled by a three-way valve, by which the drill carriage is lowered or raised, and, of course, the drill with it. A duplex force pump, to

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which is attached a governor to control the speed of pumping to requirements, supplies hydraulic power for the rams. This pump works against a constant pressure of 300". The drill bar is of 1¾" steel to form a cutting end. The drill having 8½" stroke is run by steam similar to a land drill.

Three drill frames are mounted on the boat on rails and are moved by ratchet and level attached to the axle of the drill truck wheel.

To load holes a cylinder is used having a smaller diameter than the hole and of sufficient length to admit the whole cartridge. This cylinder is slotted on one side to insert cartridge and connecting wire. To cylinder is attached a long piece of 1" gas pipe coming well above the water. The drill bar being withdrawn, this apparatus is put down into the hole and a long pole, run down through the pipe, forces the cartridge from the cylinder into the hole. The loading apparatus is then withdrawn and charge exploded by battery. From two to four drills can be operated off one scow, depending on its dimensions. Three drill boats have been employed steadily on this work for the last four years. The crews vary with the number of drills, a 3-drill machine having 12 men including blacksmiths.

Dynamite of 70% strength (as against 40% ordinarily used) is required for this work. Holes placed 6' apart and loaded with 7½ lbs. to an 8' hole gives best results. The dynamite is made in sticks 1¾" diameter and 3' long, a stick weighing 5 lbs. The shock from a blast in 16' of water is quite perceptible.

The following data compiled by the writer from foreman's reports, etc., show the results accomplished by one drill boat for the five months from April to August, 1904. Owing to the constant storms, which drive the boats from their ranges and the loss of time in getting back on said ranges, the records are not a measure of the actual capacity of the boat.

	Days of 12 hrs. worked	Holes.	Feet drilled	Lbs. powder	Ft. per hr. per 3 drills
April	49	2282	10170	8527	18
May	43	1348	6280	5624	12.2
June	50	1453	8133	6947	13.5
July	43	1512	6950	6104	13.4
August	43	1348	6478	5511	12.5

Days worked included the time to set up on ranges and the time the drill was on the range, but could not drill owing to weather. Night and day crews were worked. The time the drill lay idle in the canal basin weather-bound is not included in "days worked." The month of April shows larger results because the drill worked in a sheltered position in the canal. The depth of drilling seems

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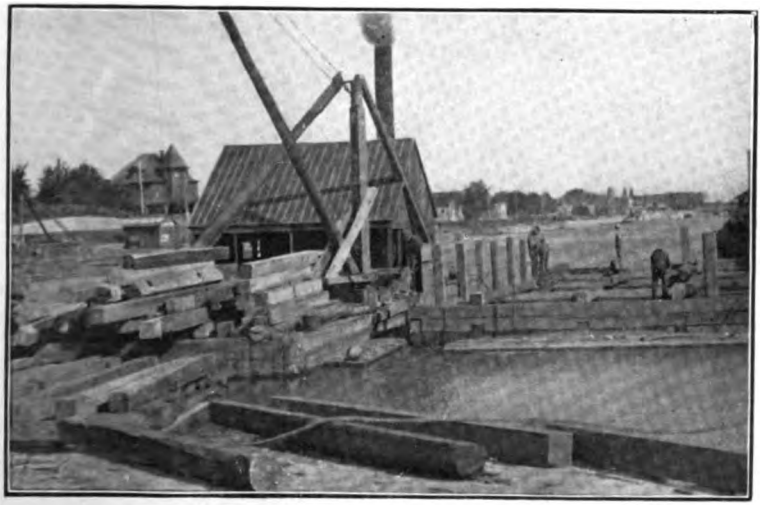

CRIB-BUILDING.

CRIB-LAUNCHING.

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to make little difference to average result as seen from June and July records, the depth of drilling in the former month being in excess of the latter. A deep hole requires an extra drill bar which takes time to insert, and deep drilling is also troublesome on account of binding, etc., but this is off-set by the extra blasting in shallower drilling, and loss of time in starting holes.

The best performance, as indicated by the record, was the drilling of 323 holes, or 1,615 feet, in 72 hours, day work, from April 4th to 9th, or an average of 22.4 feet per hour, per three drills. Best day's work was 315′, or an average of 27′ per hour.

Dredging.

The dredges used to dig this rock are of recent construction. i.e., 1902 and 1904, and possess great power. The hulls are of steel ½″ plate at sides and 1″ at bow. The dredge is pinned up on two forward spuds of 36″ x 36″ British Columbia fir running in slides. These spuds form the front corners of the hull, which gives a clear side with no projections to be knocked off. At the stern (scow type) a single spud 20″ square placed in centre of boat, and at an angle to the vertical holds boat up against the bank, and prevents swinging. This spud is geared similar to drill spuds, and has a separate engine, while forward spuds are operated strength of the machinery Kelsons, which instead of being small I-beam box girders, consist of a stiff truss the depth of hull and fastened to deck channels above, as well as to floor or bottom of boat. This greatly stiffens the vulnerable part of the boat, the bow, and prevents working of Kelsons under the pull of the engines and consequent opening of bottom and bow plates. Another feature is the carrying of the overhead truss the full length of the boat, thus affording a secure fastening of the stern anchor and a better distribution of the stress it exerts, besides adding to the general stiffness.

The power is got from two 18 x 20 horizontal engines fed by Scotch Marine Boiler 11′ x 13′, furnishing 140 lb pressure. A small pinion on the engine shaft operates a larger pinion on a shaft, to the ends of which are attached two more small pinions operating the main hoisting drum, which is 8′ in diameter. The first series of shafting is extended in bearings to the sides of the boat, and has attached to it the drums for lifting spuds. When the boat is pinned up these drums are thrown out of gear and the spuds held up by friction brake, operated on deck by the crew. To lower away the dredge it is only necessary to slack the friction brake.

The hoisting cable is of 2¼″ wire rope, and the life of a cable in digging rock with these powerful dredges is not over two months. The dredges are of the single whip variety, no system

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of pulleys or blocks being used on crane to obtain power, but a single line of cable from drum to bucket. Anchor cables are of 1¾" wire rope, while a special engine and 1¼ test chain is used for swinging.

These dredges operate a three yard bucket in rock, and a five yard bucket in clay or soft digging. Their performances vary greatly, for the frequent hauling of drills from ranges for safety causes many undrilled areas of small extent, which make difficult and almost solid rock dredging. As little as 250 yards a day is sometimes got. Tests taken of the new 1904 dredge in well drilled material loaded in skips of five yards capacity shewed an output of 4,385 cubic yards in six days of twelve hours. Deducting five hours delay for repairs, this gives an actual average of 65.5 cubic yards an hour. No effort was made for a record. Her best performance was about 1,000 yards (in tubs) in 12 hours. These are rock figures, the dredges never having been tried in soft material.

The excavated material is loaded in dump scows or tubs, according to the purpose for which it is required. No filling can be done by dump scows in less than 7′ of water. To handle skips, a large A frame steel derrick with 65′ boom, capable of lifting 20 tons, was built. To carry this a special scow 120′ x 36′ x 11′ was built, having steel trusses, etc. Owing to its breadth and stiffness it was possible to lift to the capacity of the derrick without any pinning-up apparatus.

While this derrick was an experiment it proved most succesful, being easier to handle and tow than a regular spud derrick, and besides requiring no time to pin up, it provided a large space for carrying materials.

These works are now almost completed. The tenders for putting in foundations for a 2,000,000 bushel elevator are under consideration, and with the erection of this elevator Port Colborne will possess a harbour equal to the best.

The work has been done by contract under great difficulty, caused principally by the prevalent weather conditions. Storms arose rapidly, and the drills, dredges and scows were driven from their exposed position in the lake into the basin for shelter. Scows and drill boats were sunk, and cribs wrecked and driven ashore. With the completion of the two breakwaters, however, vessels will have perfect shelter.

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DISCUSSION.

Mr. Goldmark. Mr. Henry Goldmark wished to ask the author whether the concrete slabs referred to, had been put in place over the concrete walls, and if so, whether any trouble had been experienced from cracking.

Mr. Hogan. The author replied that they had been put into service, and as yet no trouble had been experienced from cracking. They had only been in service about a year, however.

Mr. MacPherson. The chairman considered 65 to 75 yards of concrete per day, as mentioned in the paper, a pretty good record for 18 men.

Mr. Quirk. With reference to the 75% dynamite, Mr. E. McG. Quirk wished to know whether any other strength of dynamite or any other form of explosive was used, and whether there were any available data with regard to the ratio of the cubic yards moved, per pound of explosive? Also, with regard to the 65 to 75 cubic yards per day, whether this was quantity of rock as measured in place, or in the loose?

Mr. Hogan. Mr. Hogan replied that the only strength of dynamite used was 75%. In regard to the 65 to 75 cubic yards per day,—this was scow measurement.

Dr. Porter. Dr. J. B. Porter thought it was the present practice in most submarine work to use 75% dynamite. Some little time ago an engineer in charge of an important harbor improvement had told him that in all his work 75% dynamite was used when working *under* water, and it was found that it was more satisfactory than a weaker percentage. He believed the lower percentage dynamite was very seldom used under water.

Mr. Sproule. Mr. W. J. Sproule said he considered the paper a very interesting description of an enormous piece of work. He would not attempt to discuss the work in its different aspects, but wished to make a few remarks in connection with the drilling and blasting. The paper stated that for drilling and blasting a sub-marine drill boat was used, consisting of an especially strong hull, steel preferably, housed over and carrying the boiler, large steam pump drill frames, drills and hydraulic feed for same. The Montreal Harbor Commissioners had a drill boat, built by themselves, of wood entirely, 80 feet long and 27 feet wide. This drill boat had been doing some very heavy work, had three drills working, and had done work as deep as 42 feet. 75% glycerine had often been used, and inspection had shown that the drill boat was very slightly affected by the work. The drill boat mentioned in the paper was of steel, while the Montreal boat was of wood. The former was especially

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Mr Sproule. strong on the drill side, while the latter was flexible. It was also stated that the wooden scows were opened by the blasting, and that a charge at 16′ was quite perceptible. That was to be expected at an even greater depth. As he had stated, this boat had been constructed especially weak on the drill side, and worked on the theory that it should be as flexible as possible, so that it would give to the force of the explosions. The drills were on one side and the machinery, coal bunks, etc., on the other, and this side was stiff to keep the boat from shaking. This boat had now been in use nearly ten years, and had not been calked any oftener than any others of the harbor fleet. In fact it had given satisfaction in every respect, and even in drilling in deep water, 15 feet of water with the drill perhaps 15 feet in the rock, suffered little damage, and though a cheap structure, had stood the service excellently. The manner in which it had stood the work was really a surprise to those in charge, as they had expected the boat would be more or less scarred and knocked about. It would be well for the author to investigate this point a little further since it was a question whether or not the steel hull was preferable.

Mr. Hogan. Mr. Hogan thought that he had conveyed a wrong impression. There were two drill boats in use prior to the introduction of the one mentioned in the paper, and they were not found to be satisfactory for the class of drilling. This led to the decision to try the steel hull, and it had been a very great success. It had now been working for two years, night and day, and no leaks had ever been found. The latest drilling boats in Buffalo had steel hulls, and were very highly thought of there. Where a wooden boat would require to be calked, the steel hull could simply be rerivetted, which is a great deal less trouble than calking. Further, storms were encountered on the great lakes which had not to be contended against here.

Mr. Mountain Mr. G. A. Mountain wished to know whether all of the Port Colborne work was built in concrete blocks, or if Fraser's Patent Crib work was used on part of it. Mr. Fraser was one of the engineers of the Public Works Department. Most of the members would remember that he was unfortunately drowned at River du Loup. He invented the crib-work called Fraser's Patent Crib work, which consisted of moulded timber 12 x 12 x 10 feet long, reinforced with ¾″ iron, the whole fastened together by means of bolts. The idea was that it was cheaper than the concrete mass, and it was filled in just similar to ordinary timber crib work. The quantity of concrete required was a great deal less, and the speaker had been given to understand it was to be tried at Port Colborne, which caused him to raise the question. He now understood that it was to be tried in the Eastern breakwater. The idea of the patent, of course, was to cheapen the cost of the structures below water.

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and yet do permanent work. He had heard that this work was also to be tried at Depot Harbor, the work in which he had been interested previously, but he had not heard of results from there. He had seen the moulded timbers, but had never seen them put together. If the scheme would work, he thought there ought to be about a 50% saving in concrete.

Mr. D. MacPherson asked if it would not be more expensive to make than concrete blocks. Mr. MacPhers

Mr. Mountain thought it would. Another point which struck him was, that when the large steamers struck the concrete, there might be a tendency to crack it. However, the manner in which a great many cribs have been built has been simply money thrown away, and the patent crib-work ought to be an improvement. Mr. Mountain

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ELECTRICAL SECTION.

President—R. B. OWENS.
Vice-President—W. McLEA WALBANK.

Meeting Thursday, March 9th, 1905, to hear the following paper. Dr. R. B. Owens was in the chair:—

PAPER No. 225.

INTERFERENCE IN WIRELESS TELEGRAPHY.

By JOHN STONE STONE.

Introduction.

Of the various problems which have been presented in the course of the development of the new art of wireless telegraphy, none is of greater interest to the engineer and none is of more far-reaching importance from the industrial and commercial standpoint than that of rendering the receiving instruments of wireless telegraph stations immune from *interference*.

There are two principal kinds of interference.

1st. Interference which arises from electrical charges which accumulate upon the vertical oscillator under various conditions of weather, provided the vertical oscillator has no adequate electrical connection to the earth.

2nd. Interference which arises from such stray electromagnetic waves as are produced by lightning, by magnetic storms, by sparks in neighboring circuits, such for instance as occur in trolley circuits, and also from the electromagnetic waves emanating from wireless telegraph stations other than that with which communication is desired.

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Interference Due to Static Charges.

The interference which results from the first of these two sources is readily overcome since the oscillator of a wireless receiving station may always be given a metallic connection to the earth sufficient to maintain it clear of statical charges without in any appreciable degree interfering with its operation as a receiving oscillator.

Thus for instance if the vertical oscillator includes a condenser insulating a portion of the vertical oscillator from the earth, the condenser may be shunted by a coil of inductance so large that

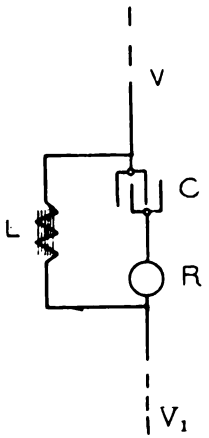

Fig 1.

for the high frequencies employed in wireless telegraphy it will operate practically as an open circuit, whilst affording a ready path to earth for the electrical charges which, in its absence, would accumulate upon the vertical oscillator and produce disruptive discharges to earth.

Again, if a highly sensitive detector or receiving device be included directly in the vertical receiving oscillator, such an inductance coil may be placed in shunt to the receiver without appreciably affecting its sensitiveness. The coil will then serve as a by-path for the currents due to the passage of the charges of the vertical oscillator to the earth.

Another device which may serve to still further protect the receiver under these conditions is that illustrated in Fig. 1, in which

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V and V_1 are portions of the vertical oscillator system, L is a coil of large inductance, R is the receiving device, and C is a condenser of capacity so large as not to impede appreciably the passage of the high-frequency oscillations of wireless telegraphy while acting practically as an open circuit for the more slowly varying currents by which the vertical oscillator is maintained free of static charges.

The greatest security from this form of interference is however obtained by providing the vertical receiving oscillator with an adequate conductive connection to earth and by placing the receiving device in a local circuit made resonant by a coil and a condenser to the frequency of the electrical oscillations to which the receiver is intended to respond.

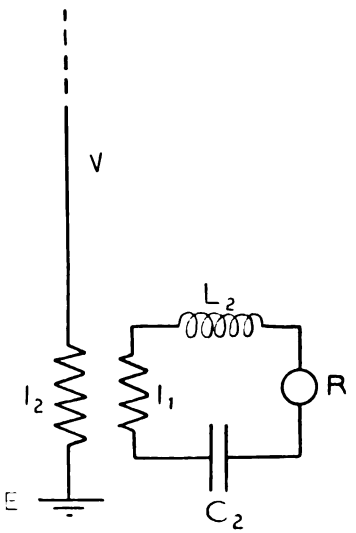

Fig 2

An example of such an arrangement is shown in Fig. 2, in which VI_2E is the vertical receiving oscillator, I_1 and I_2 are the two coils of a high frequency transformer, R is the receiver, C is a condenser and L_2 is an inductance coil.

The manner in which the local circuit containing the receiver is made resonant to the frequency of the oscillations to which it is intended to respond will be considered later in this paper. It is

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sufficient here to note that the local circuit being resonant to a frequency sufficiently high for the purposes of wireless telegraphy, will not be appreciably affected by the more slowly varying currents in the vertical oscillator by which the latter is maintained free from static charges.

Interference due to Electromagnetic Waves.

Coming now to the prevention of interference by electromagnetic waves such as emanate from other wireless stations than that with which it is desired to hold communication, and to the prevention of interference by stray electromagnetic waves, we find that the solution of the problem depends upon the character of the message-bearing wave, the energy of which it is desired to convey to the receiving device, and also upon the character of the disturbing waves, the energy of which it is desired to exclude or divert from the receiving device.

We can control the character of the waves whose energy we wish to receive, by suitably designing the apparatus to be used at the transmitting station, but we have no control over the character of the disturbing waves except in so far as these arise from wireless stations within operative range of the receiving station.

The simplest solution of this problem is to cause each transmitter to send out its signals by means of *persistent trains of simple harmonic waves* of a frequency materially different from that employed by any other transmitter within operative range of the receiving station with which communication is to be maintained and to make each receiver responsive only to *persistent trains of simple harmonic waves* of the frequency employed by the transmitter with which it is in communication.

By this means the system is rendered selective and becomes a multiple system of telegraphy, permitting the operator at each station to select the station with which he wishes to hold communication to the exclusion of all the other stations, and by which a number of messages may be transmitted simultaneously in a given region without interfering with one another.

Since the stray electromagnetic waves arising from lightning etc., are not persistent trains of simple harmonic waves, but partake more of the character of isolated impulses, the receiver in such a system does not respond to such stray electromagnetic waves and it is therefore also freed from interference which would otherwise arise from such sources.

The manner in which a transmitting station is made to develop persistent trains of simple harmonic electromagnetic waves

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of one frequency to the exclusion of waves of other frequencies, though simple in itself, in practice requires the strictest attention to certain details, and these may be best understood by the consideration of a concrete case, this being the manner in which such problems are usually presented to the engineer if not to the inventor.

Transmitter.

In modern wireless telegraphy the messages are transmitted by electromagnetic waves which are horizontally polarized at the earth's surface, and which are developed by electrical oscillations set up in an electrical oscillator whose axis is normal to the surface of the earth and which is connected to the earth at its lower extremity.

The reason for employing waves of this type and so developed, is that such waves have, at the earth's surface, no component of electric force parallel to the surface and no component of the magnetic force normal to or cutting that surface, except in the immediate neighborhood of the base of the transmitting oscillator. As a result they do not tend to induce currents in the surface of the earth as they travel away from the transmitter except where the surface of the earth deviates from the plane of polarization of the waves at that surface. The energy which would otherwise be rapidly dissipated through the production of induced currents in the earth is therefore conserved in the waves. Moreover when a deviation occurs between the plane of the earth's surface and the plane of polarization of the waves at the earth's surface, the currents induced in the surface of the earth are such as to bend the wave front into a position normal to the surface with the result that the waves travel over and around mountains and in fact follow the earth's surface whatever be its contour, instead of tending to travel in straight lines like ordinary light waves and as would be the case with vertically polarized electromagnetic waves.

For a more complete exposition of these points see a paper read by the Author at the International Electrical Congress held at St. Louis, Sept. 12 to 17, 1904, and reprinted in the Electrical Review, New York, Oct. 15, 1904.

There is not space in this paper to discuss in detail the development of the waves described above, but their genesis and mode of propagation is clearly suggested by Figs. 3 to 8. Fig. 3 and Fig. 4 illustrate the development of a wave by free electrical oscillations in a straight wire AoB, the curved lines indicating a line of electric force in its various phases from $t=0$ to $t=\frac{5}{8}$ T, where T is the time of a complete free electrical oscillation in the

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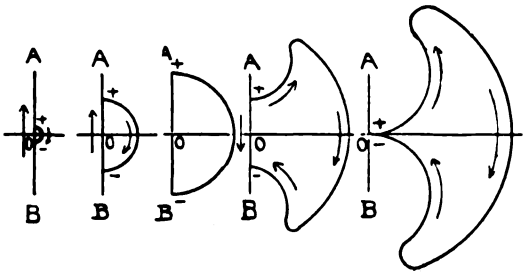

Fig. 3

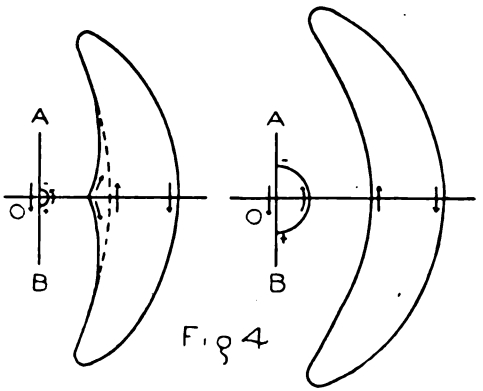

Fig. 4

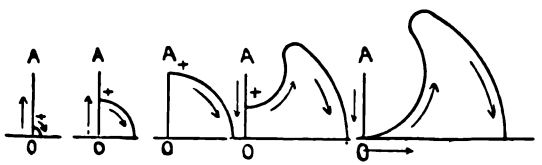

Fig. 5

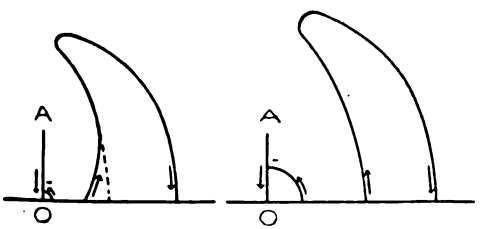

Fig. 6.

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wire. In Figs. 5 and 6 the genesis of a wave from a vertical linear oscillator Ao earthed at its lower extremity is illustrated, and in Figs. 7 and 8 the effect of an elevation and depression in the surface of the earth upon the wave fronts at that surface is indicated.

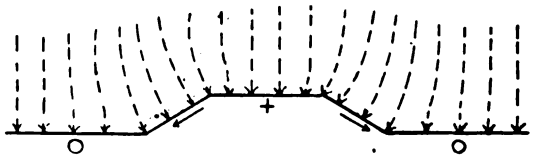

Fig 7

We may next consider the earth connection of the transmitting oscillator and the nature of the support for the oscillator.

Although, by the use of such waves as are described above, normally the current density in the surface of the earth at a distance from the transmitting oscillator is rendered excessively small, nevertheless at, and in the immediate neighborhood, of the base of the vertical oscillator, the current density is in general very great. Moreover since the current is of high frequency, it tends to flow only on the surface of the earth. For this reason the usual

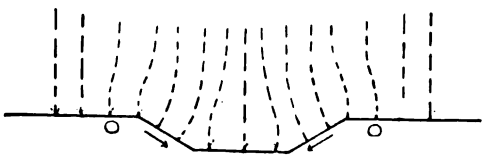

Fig 8

specifications for obtaining a good earth connection, which involves burying a conductor of large area so deep in the ground that it shall be in permanently moist earth, are no longer advantageous, and in a properly constructed wireless telegraph station the conductivity of the *surface of the earth* in the immediate neighborhood of the base of the oscillator is artificially increased by a *superficial ground-plate* composed of sheet metal, or of wire netting, extending radially from the base of the oscillator and covering as large an area about the base of the oscillator as is available for the purpose and consistent with reasonable economy.

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Since the waves are horizontally polarized, the supports for the vertical oscillator, such as masts and guy-ropes, should either be of insulating material, or if of metal, they should be divided by insulation into sections short compared to one-half the wave-length of any of the waves to be employed. The reason for this is that the fundamental free period of vibration of a linear conductor is such as to cause it to respond most energetically to waves of twice its own length. For such wave-lengths, therefore, the linear conductor would absorb an undue amount of the energy of the waves and moreover because of the rise of potential which occurs at the ends of the conductor for waves of such length it would be difficult to insulate the conductor from the earth or adjacent portions of the support of the vertical oscillator.

We come now to the vertical oscillator itself. This in general consists of two parts, the elevated conductor *per se* and the devices through which it is connected with the earth.

We shall here consider the relatively simple case in which the elevated conductor is a straight, cylindrical copper wire of length a and radius ρ

Both theory and practice show that the electrical vibrations in such a wire connected directly to the earth at its lower extremity correspond very closely to the transverse vibrations of a heavily damped stretched string.

If such a wire be charged to a high potential and be then permitted to discharge to earth, the electrical oscillations developed in it, and therefore also the electromagnetic waves radiated by it will not be simple harmonic in type and will not be persistent. These waves will not therefore correspond to the sound waves given out by a tuning-fork, but will be of the character of those given out by a heavily damped violin string plucked at its centre.

The fundamental of the waves given out by such an oscillator has a wave-length which very closely approximates four times the length of the wire, and this is accompanied by all the odd harmonics. The oscillations are so much damped by the energy drawn off from the oscillator by radiation as to make the resulting waves more nearly the equivalent of an impulse than of a sustained or persistent train of waves.

If, however, the elevated conductor be not directly connected to the earth, but be connected to it through an inductance coil, both theory and practice show that its electrical vibrations correspond to the transverse vibrations of a heavily damped stretched string with a mass attached to its centre.

The effect of the load at the centre of the stretched string and of the inductance at the base of the vertical wire is to increase the

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persistency of the vibrations, to minimize the importance of the harmonics and to lower the frequency of the fundamental. It might therefore seem that in order to cause the vertical oscillator in question to radiate a persistent train of simple harmonic waves of a predetermined frequency, it would be sufficient to charge the

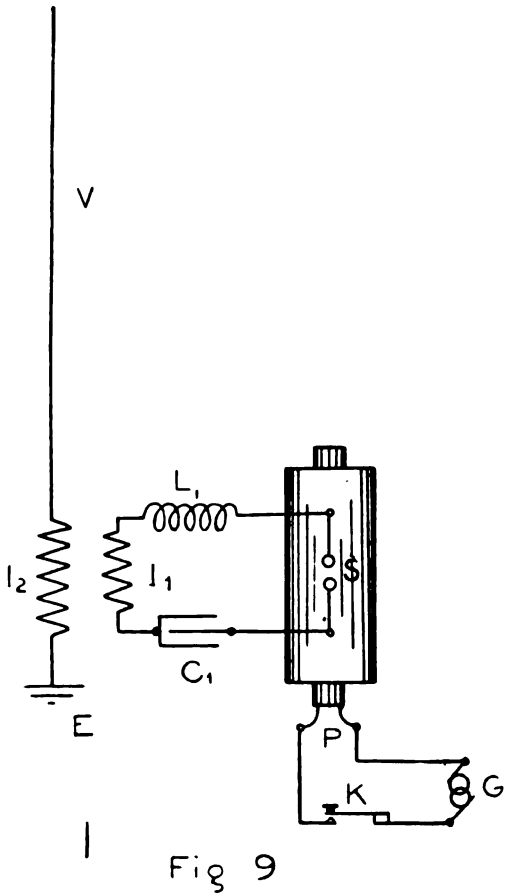

Fig 9

vertical wire to a high potential and permit it to discharge to earth through an inductance coil of suitable dimensions.

This indeed was the plan adopted in the first crude attempts at producing a selective system of wireless telegraphy. This method necessitates the use of waves of much lower frequency than that normally produced by natural vibrations in the vertical wire *per se*.

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The degree of persistency of oscillations so obtained, however, is not as great as is required in practice. Such persistency as is obtained is gained at the expense of the amplitude of the current oscillations in the vertical and at the expense of the radiating power of the oscillator, the latter being *caeteris paribus* less for low than for high frequencies. Moreover the spark in the vertical oscillator which normally dissipates an undue amount of the energy of the oscillations, has its resistance enhanced by the reduction of the amplitude of the current oscillations due to the presence of the inductance coil.

This latter difficulty may in a measure be overcome at the expense of any increase of the energy supplied to the oscillator, by shunting the spark gap by a condenser of large capacity. The discharge of the condenser across the spark gap increases the current through the spark and thereby reduces its resistance and damping effect upon the oscillations. The damping effect of the radiation still remains and the persistency is still too much limited for practical purposes.

So far we have considered only the *natural oscillations* of the vertical oscillator which are produced by charging the elevated conductor to a high potential and then permitting it to discharge to earth. When, however, a high degree of persistency, a pure sine wave and a great amplitude of oscillation are desired, the spark gap is removed from the vertical oscillating circuit and a simple harmonic electromotive force is impressed upon the vertical oscillator in its place. The resulting vibrations in the vertical oscillator are then *forced simple harmonic vibrations*. In order that they may be of great amplitude, the frequency of the impressed force is made to correspond to the fundamental of the vertical oscillator or to one of its harmonics, in which cases the reactance of the vertical oscillator is nil.

A simple arrangement for producing forced, simple harmonic vibrations in the vertical oscillator is shown in Fig. 9 in which G is an alternating current generator, k is a key, P shows the connection to the terminals of the primary of a spark coil, S is a spark gap between the terminals of the secondary of the spark coil C_1 is a condenser, L_1 is an inductance, I_1 and I_2 are the primary and secondary coils of a high-frequency transformer, V is the vertical wire and E is the earth.

There is a variety of ways in which substantially the same result may be accomplished, but there is not space in this paper to consider more than one arrangement.

For the type of elevated conductor which we are here considering i.e., a cylindrical copper wire of length a and radius ρ the reactance

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of the elevated conductor *per se* is given with a degree of approximation ample for engineering calculations by the expression;—

$$Z = -Lv \cot \frac{na}{v}$$

where $L = 2 \log_\epsilon \frac{4a}{\rho} - k$

and where $k = 5{\cdot}584 - 3{\cdot}169\left(\frac{na}{v}\right)^2 + 0{\cdot}3269\left(\frac{na}{v}\right)^4$ for values of a between 0 and $\frac{\pi v}{2n}$

In these expressions v is the velocity of light and n is the periodicity of the impressed force or $\frac{2\pi}{T}$ where T is the time of a complete oscillation.

The reactance Z therefore vanishes when $n = \frac{2\pi}{t} = m\frac{\pi v}{2a}$ where m is an odd integer. The wave lengths corresponding to this condition are therefore $\lambda = vT = \frac{4a}{m}$. The wave-length of the fundamental is therefore 4a and the harmonics are all odd.

For frequencies lower than the fundamental, the reactance is negative or a capacity reactance. For frequencies between that of the fundamental and its first harmonic the reactance is positive or an inductance reactance. For frequencies between that of the first even harmonic and the first odd harmonic the reactance is again negative or a capacity reactance. In other words, the reactance of the vertical wire measured at the source or driving point of the system is either that of a condenser of capacity $S' = \frac{1}{Lvn \tan \frac{na}{v}}$ or of an inductance $L' = \frac{Lv}{n} \cot \frac{na}{v}$ depending upon whether $\cot \frac{an}{v}$ is positive or negative.

The condition for zero reactance in the vertical oscillator system is obviously $Z + Z_0 = 0$ where Z_0 is the reactance of the apparatus connected between the vertical wire and the earth. Z^0 must therefore be an inductance reactance for frequencies which make the reactance of the vertical wire a capacity reactance and

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(1) The value of k here given has been determined empirically, the remainder of the formula being based upon a theoretically deduced working theory described in the paper referred to on page 133. A more complete expression for L will be given elsewhere.

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conversely it must be a capacity reactance for frequencies which make the reactance of the vertical wire an inductance reactance.

The curve shown in Fig. 10 gives the observed apparent capacity of vertical wires 0″.08 in diameter varying from 40 to 180 feet in length, when the periodicity of the impressed force is 9.78×10^6. In other words it gives the observed apparent capacity of vertical wires for values the angle of $\frac{na}{v}$ from 0.3976 to 1.790 and for values of the ratio $\frac{4a}{\rho}$ from 47,520 to 213.800.

The reactance Z_0 of the apparatus through which the vertical wire is connected to ground may most simply be made

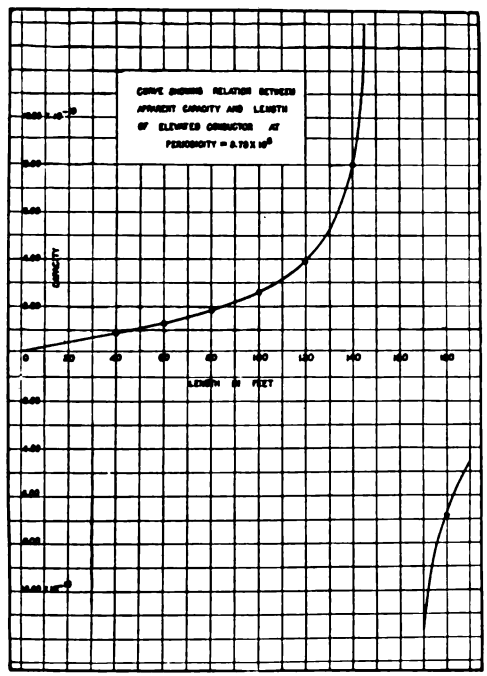

Figure 10.

negative, when this is necessary, by the insertion of a condenser in series with the coil I_2, but this result may be accomplished in a variety of ways for the description of which there is not space in this paper.

It will be seen that by making $Z + Z_0 = 0$, or Z_0 equal, but opposite in sign to the reactance of the elevated conductor, powerful

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oscillations of any desired frequency may be developed in the vertical oscillator by means of forced vibrations, whereas when the natural oscillations of the vertical oscillator are resorted to the frequency must necessarily be less than that of the fundamtntal of the oscillator.

Concerning the arrangement illustrated in Fig. 9, there is much of detail which requires attention in order that the apparatus shall satisfactorily fulfil the requirements of radiating a persistent train of simple harmonic waves. For instance, if a dielectric having considerable electrostatic hysteresis be employed in the condenser, a surprisingly large amount of energy will be dissipated in this dielectric. The magnitude of this loss is due to the fact that the energy dissipated increases both with the potential difference employed at the terminals of the condenser and also with the frequency. Since potential differences developed at the terminals of the condenser amounting to 50,000 volts and oscillations having frequencies of 5,000,000, are not unusual in wireless telegraphy, it is easy to see that the losses in the dielectric of a condenser in a wireless telegraph circuit are of a far greater order than that in the dielectric of condensers employed in the usual power or lighting circuits.

Moreover the specific inductive capacity of most dielectrics is a function of the density of the displacement current in the dielectric, and when such dielectrics are employed in the condenser in an oscillating circuit the resulting oscillations are not simple harmonic in form and are not isochronous throughout the train.

Air condensers should therefore be used in wireless telegraphy to the exclusion of any other type pending the publication of the results of certain investigations which are being conducted with the view of supplying a dielectric of high dielectric strength and constant specific inductive capacity.

The coils used in wireless telegraphy should not have iron cores except the iron be very finely comminuted and imbedded in a non-hygroscopic dielectric matrix. It has even been found by the author that coils wound on a wooden cylinder do not operate satisfactorily when used in the oscillating circuits of wireless telegraphy. The coils for this purpose are best constructed by winding a few turns of bare copper wire in a single layer on a skeleton frame made of ebonite, care being taken to separate the turns by such an amount that the sum of the air spaces between the wires of the turns is equal to or slightly greater than the sparking distance in air corresponding to the greatest potential difference liable to occur at the terminals of the coil when the apparatus is in operation.

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If the local oscillating circuit C_1 I_1 L_1 S of the arrangement shown in Fig. 9 were isolated, its oscillations would be expressed by $i = \frac{e}{L} \frac{1}{\sqrt{\frac{1}{LS} - \frac{R^2}{4L^2}}} \epsilon^{-\frac{R}{2L}t} \cdot \sin \sqrt{\frac{1}{LS} - \frac{R^2}{4L^2}}$ where i is the current, e is the potential to which the condenser C_1 is charged at the time when the spark occurs at S, L is the inductance of the circuit, R is the resistance and S is the permittance or electrostatic capacity of the condenser.

If the oscillator is at all persistent $\frac{R^2}{4L^2}$ is negligible compared to $\frac{1}{LS}$, and the expression reduces to

$$i = e \sqrt{\frac{S}{L}} \epsilon^{-\frac{R}{2L}} \cdot \sin \frac{t}{\sqrt{LS}}$$

The time required to fall to $\frac{1}{\epsilon}$ th of their initial amplitude is therefore $t = \frac{2L}{R}$

The number of oscillations per unit of time is $\frac{1}{2\pi \sqrt{LS}}$.

The measure of the persistency of the circuit is therefore proportional to $\sqrt{\frac{L}{R^2S}}$

For a given frequency, $Ln = \frac{I}{Sn}$ so that the persistency for a given frequency is proportional to $\frac{Ln}{R}$, where n is 2π times the frequency.

An isolated circuit of this type may be made to give extremely persistent simple harmonic oscillations, but if it be given a large co-efficient of mutual induction with another oscillator of relatively low persistency, such as the vertical oscillator VI_2E of the arrangement shown in Fig. 9, two things happen. In the first place the oscillations of the circuit are in general no longer simple harmonic, but are broken up into two simple harmonic oscillations of different frequencies, and in the second place the persistency is greatly reduced.

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To overcome this difficulty it is necessary either to make the magnetic leakage of the high frequency transformer, connecting the local oscillating circuit with the vertical oscillator, unusually large, or else to add to the local oscillating circuit an inductance coil L_1 with sufficient inductance to swamp by its effect the reaction from the secondary circuit.

When intense radiation is desired, it is necessary to make the capacity S of the condenser C_1 in the local oscillating circuit large compared to S′ the apparent capacity of the elevated conductor *per se*, for the frequency employed.

Receiver.

Since the electromagnetic waves to be received at a wireless telegraph receiving station are horizontally polarized at the earth's surface, an electrical oscillator whose axis is normal to the earth's surface is employed at the receiving station. This oscillator may either be connected to earth at its lower extremity or it may be connected to a device having reactance equal for all frequencies to the reactance of the vertical oscillator. It is to be remembered in this regard that at the receiving station we are not concerned with what becomes of the energy which is dissipated by the reradiation of the energy from the receiving vertical oscillator.

We shall consider again a simple concrete case, and shall assume the elevated conductor to be a cylindrical copper wire of length a and radius ρ as in the case of the transmitter, though it must by no means be assumed that the elevated conductor at the receiving station must necessarily be similar to that at the transmitting station, or, in fact, that it must bear any resemblance to that at the transmitting station except in so far as its axis is preferably normal to the surface of the earth.

As in the case of the transmitting station, only one simple arrangement of the apparatus sufficient to give the desired result will here be considered. By this arrangement messages transmitted by means of persistent trains of simple harmonic electromagnetic waves of a predetermined frequency may be received to the exclusion of messages transmitted by similar waves of materially different frequencies, and without interference by impulsive waves. Such an arrangement of the circuits and apparatus is shown in the diagram 11. In this arrangement the receiving device which is indicated at R is placed in a local circuit C_3 I_3 L_3 R which is made reasonant to the frequency of the waves to which the station is intended to respond, and a second reasonant circuit C_2 I_2 L_2 I_2' reasonant to the same frequency and called a "weeding-out circuit", is interposed between the first mentioned circuit and the vertical oscillator.

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The branch circuit consisting of the coil I_1, and condenser C_1 is not, when taken by itself, reasonant to the same frequency as the other local circuits, but is so proportioned that when connected as a branch circuit, forming a part of the vertical oscillator system, the latter shall respond most energetically to persistent trains of waves of that frequency falling upon the vertical wire.

The way in which this is accomplished is perhaps more easily seen by a graphical demonstration than by the use of the analytical solution, though the latter is by no means difficult.

The curves in Fig. 1 illustrate the point in question. Curve 1 represents the reactance of the vertical wire measured at its point of attachment to the loop circuit, for varying periodicities of the

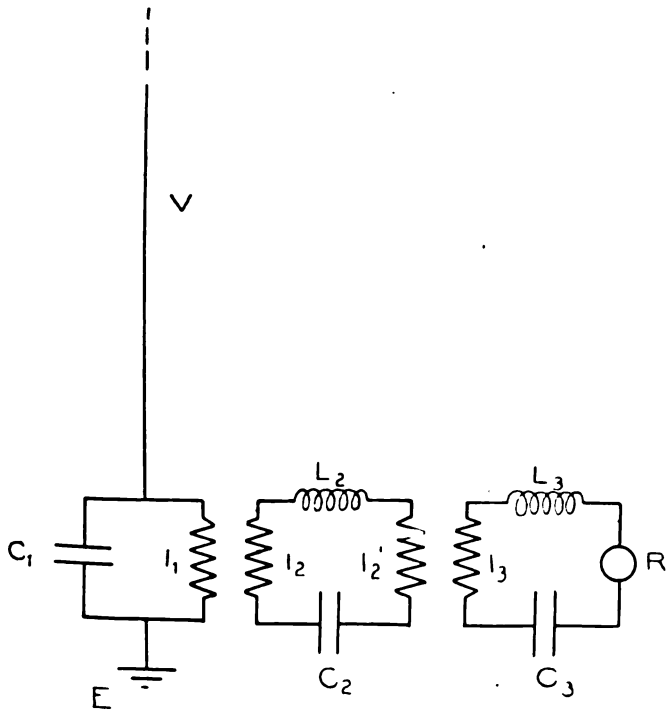

Fig 11

impressed force. It will be seen that the periodicity of the fundamental of the vertical wire is at the point n_1'', where the reactance first vanishes. The first even harmonic is at n_2'', and the periodicity of its first odd harmonic is at n_3'', where the

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reactance again vanishes. Normally therefore curve 3, which is the current curve for varying periodicities of the impressed force on the vertical wire would show maxima at n_1'' and at n_3''. The reactance of the loop circuit for varying periodicities of the impressed force, measured across the points of its attachment to the vertical wire and earth connection is shown in Curve 2. The total reactance of the vertical oscillator measured at the earthed terminal is the algebraic sum of the two reactances shown in Curves 1 and 2, and as a result the current curve 3 shows maxima, not at n_1'' and n_3'', but at periodicities n, n'' and at a periodicity slightly higher than n_3''.

These are the points at which the reactance of the loop circuit is equal, but opposite in sign, to that of the vertical wire.

The periodicity of the local loop circuit *per se* is n' and for this periodicity the current in the vertical wire is practically nil.

The "weeding-out circuit" and the circuit containing the receiver are both resonant to the periodicity n, so that for persistent trains of waves of that periodicity the energy of the oscillations set up in the vertical oscillator is transmitted directly to the receiver, but persistent trains of waves of other frequencies, either produced by slight response in the vertical oscillator or else produced oscillations of the periodicity n'', or of a periodicity slightly higher than n_1'' have little effect on the receiver. To such periodicities the "weeding-out circuit" and the circuit containing the receiver are extremely irresponsive so that the receiving device receives but an inappreciable amount of the energy of the waves.

In the case of impulsive waves the vertical wire tends to respond only to its own natural rates of vibration as affected by the loop circuit, that is to say, it tends to oscillate at periodicity n'' and to upper harmonics. Such waves acting on the vertical wire, have little tendency to develop oscillations of the natural period of the loop circuit as affected by its connection with the vertical wire, namely n, and the receiver is therefore also protected from the effects of such impulsive waves.

All that has been said regarding the effects of electrostatic and magnetic hysteresis in the description of the transmitting station applies with added force to the apparatus at the receiving station. It is, in fact, much more important to exclude the effects of hysteresis from the receiving circuits than from the transmitting circuits, and it may be laid down as an important rule that under no circumstances shall solid or liquid dielectrics be used in the receiving circuits.

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Moreover the injuction in regard to making the mutual inductance small between oscillators at the transmitting station applies in the case of the resonant circuits at the receiving station, since if the mutual energies of the related resonant circuits be not small compared to their self energies, the resonant circuits will modify one another's natural periods and each circuit will respond to more than one periodicity.

Finally it may be said the measure of the selectivity of a reasonant circuit is proportional to $\sqrt{\frac{L}{R^2 S}}$, this expression being the same as that found in connection with the persistency of an oscillating circuit. For a given periodicity, therefore, the selectivity is proportional to $\frac{Ln}{R}$

So great is the selectivity of resonant circuits constructed of air condensers and properly designed inductance coils that there is no difficulty in adjusting such circuits to resonance for a given frequency with an error of less than one part in 3,000.

The importance of the "weeding-out circuit" in the receiving station becomes apparent when we observe that the selectivity of the receiving vertical oscillator is greatly diminished by the dissipation of energy, which results from the re-radiation of energy by tnat oscillator and that the selectivity of the resonant circuit containing the receiver may be greatly diminished by the energy absorbed by the receiver and utilized in its operation.

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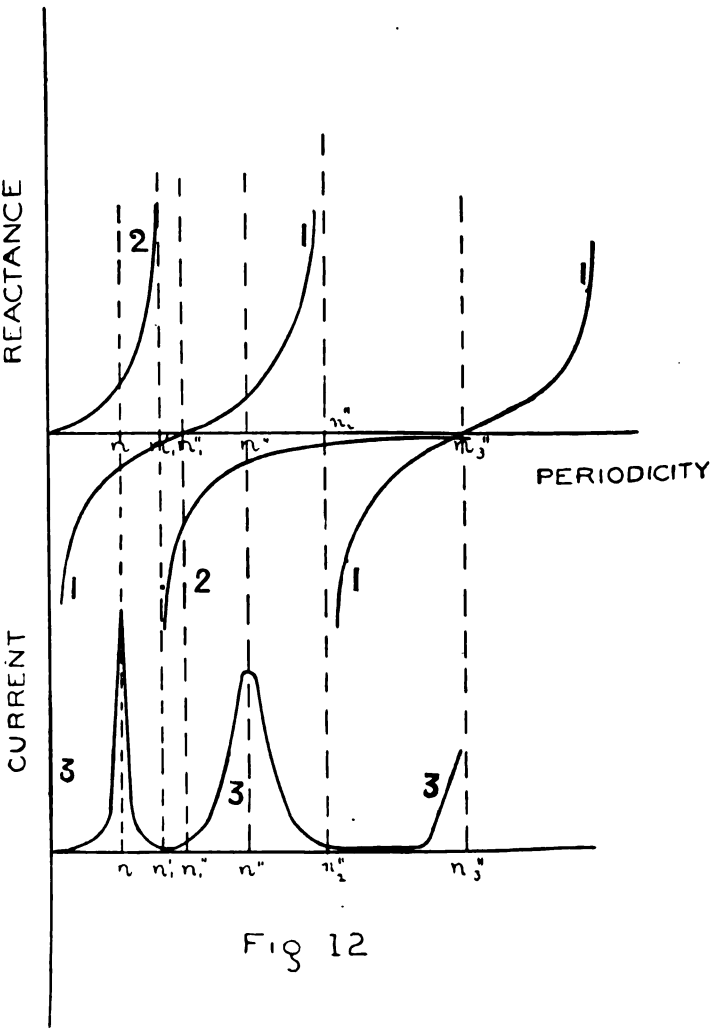

Fig 12

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BUSINESS MEETING.

A business meeting for the opening of ballots for the election of members was held on Thursday, March 16th, 1905, Mr. Phelps Johnson in the chair. Messrs. W. J. Sproule, A. A. Bowman, G. Legrand, J. A. Jamieson and J. W. Heckman, being appointed scrutineers, declared the following elected:—

MEMBERS.

J. B. COCHRANE.
V H. DUPONT.
E. S. FRASER.
J. E. HARDMAN.
J. L. HARRINGTON.
F. T. PEACOCK.

ASSOCIATE MEMBERS.

D. W. BURPEE.
L. M. CAIRNIE.
E. C. H. DOWSON.
A. T. FRASER.
A. J. GAYFER.
R. A. HARRY.
J. P. LECLAIRE.

TRANSFERRED FROM CLASS OF ASSOCIATE MEMBER TO CLASS OF MEMBER.

W. D. BAILLAIRGE.
W. W. COLPITTS.
T. R. HENDERSON.
N. J. KER.

TRANSFERRED FROM CLASS OF STUDENT TO CLASS OF ASSOCIATE MEMBER.

H. B. CRAIG.
H. M. DIBBLEE.
G. B. HUGHES.
J. H. JACKSON.
Y. D. KIRTON.
R. H. SQUIRE.

STUDENTS.

F. W. ANDERSON.
W. P. BELL.
W. G. B. BROWN.
A. BURNETT.
P. DAVIS.
J. G. DICKINSON.
F. G. DUNNING.
S. E. FARLEY.
H. L. FORBES.
P. R. GRANSAULL.
A. M. HAMILTON.
A. E. HEPBURN.
L. B. KINGSTON.
H. A. LUMSDEN.
G. E. McCUAIG.
C. H. McDOUGALL.
G. McDONALD.
E. E. CLAWSON.
L. H. COLE.
G. E. COLE.
R. P. COWAN.
A. McMEEKIN.
T. C. MAHON.
E. N. MARTIN.
J. H. H. NICOLLS.
W R. MOTLEY.
J. F. W. OWEN.
N. F. PEDLEY.
J. G. REID.
H. E. SCOTT.
J. W. SIMARD.
O. M. STITT.
R. A. WEAGANT.
F. G. WICKWARE.

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MECHANICAL SECTION.

Meeting Thursday, March 23rd, 1905, Mr. Phelps Johnson in the chair. Mr. W. H. Laurie read the following paper:—

PAPER No. 226.

GAS AS A MOTIVE POWER, AND ITS RELATIVE COST.

By W. H. LAURIE, M. Can. Soc. C. E.

Gas was first introduced in the year 1793 by Murdoch, for illuminating purposes, and the first reciprocating gas engine was introduced one year later by Street, and in 1801 a second patent was taken out on a gas engine, setting forth the advantages to be gained by compressing the gas and air before entering the explosion cylinder. These two patents embodied two of the fundamental principles upon the merits of which later engines were made a practical success, although a period of sixty years elapsed from the date of these patents before a practical gas motor was made, and even then the consumption of gas per horse-power was about 100 cubic feet per hour per horse-power, six or seven times what it is to-day. It was not until 1876 that a really successful engine was produced by Otto, and from that date the gas engine has been gradually becoming a more serious competitor of the steam engine, and has within the last few years reached a stage where it has entirely out-distanced the moderate sized steam engine, owing to the high efficiency obtained from recent improvements in the details of construction together with improvements in the apparatus for generating the gas.

Gas.—Any combustible material, when subjected to a high temperature either by its own combustion, or, by the application of external heat, will be partially, or wholly converted into gas. There are three principal processes for making gas from coal, the products of which are known respectively as:—

1st.—Illuminating, or coal gas.
2nd.—Water and producer gas.
3rd.—Semi-water gas.

Illuminating Gas.—The first (illuminating, or coal gas) is usually made from bituminous coal, as that contains a larger percentage of volatile matter, and less fixed carbon than anthracite,

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it being only the volatile matter that is converted into gas, the fixed carbon remaining in the retorts in the form of coke.

The coal is placed (in charges from two to four hundredweight) in fire clay retorts, hermetically sealed, which have been heated to the necessary temperature for gas making (from 1,800 to 2,000 degrees). The coal is subjected to this heat for a period of five or six hours, by which time it will have given off all the gas it is capable of evolving.

The gas, on leaving the retorts, passes through a pipe leading to the hydraulic main, where a portion of the tarry matter is deposited, and the temperature reduced to about 140 or 150 degrees.

From the hydraulic main it is drawn off into a surface condenser, where the gas becomes cooled to normal temperature, about 60 degrees, and deposits the tar and aqueous vapor previously held in suspension.

From the condenser the gas passes to the exhauster, the function of which is to remove the gas from the heated retorts as fast as it is produced, and at the same time force it on with sufficient force to pass it through the various materials used in its purification.

From the exhauster the gas enters the apparatus intended for the abstraction of the ammonia, consisting usually of a scrubber, or washer, or both. The function of these devices is to remove all the ammonia and some of the carbonic acid and sulphuretted hydrogen in the gas.

From the scrubbers the gas passes to the purifiers, where the remaining impurities—carbonic acid and sulphuretted hydrogen—are abstracted by means of lime and oxide of iron. Under this process the following are the approximate results obtained from a ton of Newcastle coal, according to an authority on the subject:—

Gas (10,000 feet)	380 lbs.
Tar (10 gals.)	115 "
Ammoniacal liquor	177 "
Coke (absolute)	1,568 "
	2,240 "

Water Gas.—About 1784, Cavendish discovered that hydrogen, which had been previously known as "Inflammable Air," was one of the component parts of water, but no practical use was made of the discovery until 1824, when J. H. Ibbetson took out a patent for a special method of making illuminating gas, by passing steam through a mass of incandescent carbon; and even then no apparatus was designed that could be considered a commercial success, until about 40 years after. Among the water gas processes in use to-day,

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that of the Loomis-Pettibone is one of the most widely known in America.

This plant consists of two generators from five to eleven feet in diameter, and from twelve to eighteen feet in height, and steam boiler, with necessary valves, etc. The generators are lined with firebrick, with firebrick arched grates, ash-pit and flue to boiler in the bottom. They are provided with a door on top for firing and admission of air, two cleaning doors above the grate and one below the grate into ash-pit.

The vertical boiler is of the multitubular type, and of suitable size to correspond to the generators, and is connected at its base with the generators. An exhauster is connected with the top of the boiler beyond the producer valve.

In Operation.

The generators are supplied with a layer of coke about five feet thick, which is ignited at the top, the exhauster creating a downward draft; when this body of fuel is ignited, coal is charged at intervals, raising the fuel bed to about eight feet above grates, and there maintained.

Bituminous coal is generally used and is fed through the feed door in the top of the generator. Air is also admitted through the same doors and by means of the exhauster is drawn down through the grates and ash-pits of the generators, up through the vertical boiler and then to scrubbers and exhauster, from which it is delivered to the gas holder.

When the exhauster has brought the fuel up to a state of incandescence, the charging doors are closed, and valves altered, so as to direct the flow of gas as desired. Steam is then turned into the ash-pit of one generator, and, in passing through the incandescent coal, is decomposed, forming gas. From the first generator the gas passes through the connecting pipes shown near the top of the generators, and down through the second generator, then into the base of boiler and up through the same, and thence, after being washed in a scrubber, is passed to gas holder.

Water gas is made for about five minutes, when the temperature of the fuel beds having been considerably reduced, the steam is shut off and the process reversed.

The process of making water and producer gas is alternated at intervals of five minutes or so. In making the second run of water gas the course of the steam is reversed, i.e., the steam is turned into the ash-pit of No. 2 generator and down through No. 1.

While the fires are being blasted, and during the making of water gas, the hot gases, in passing through the boiler, give up a

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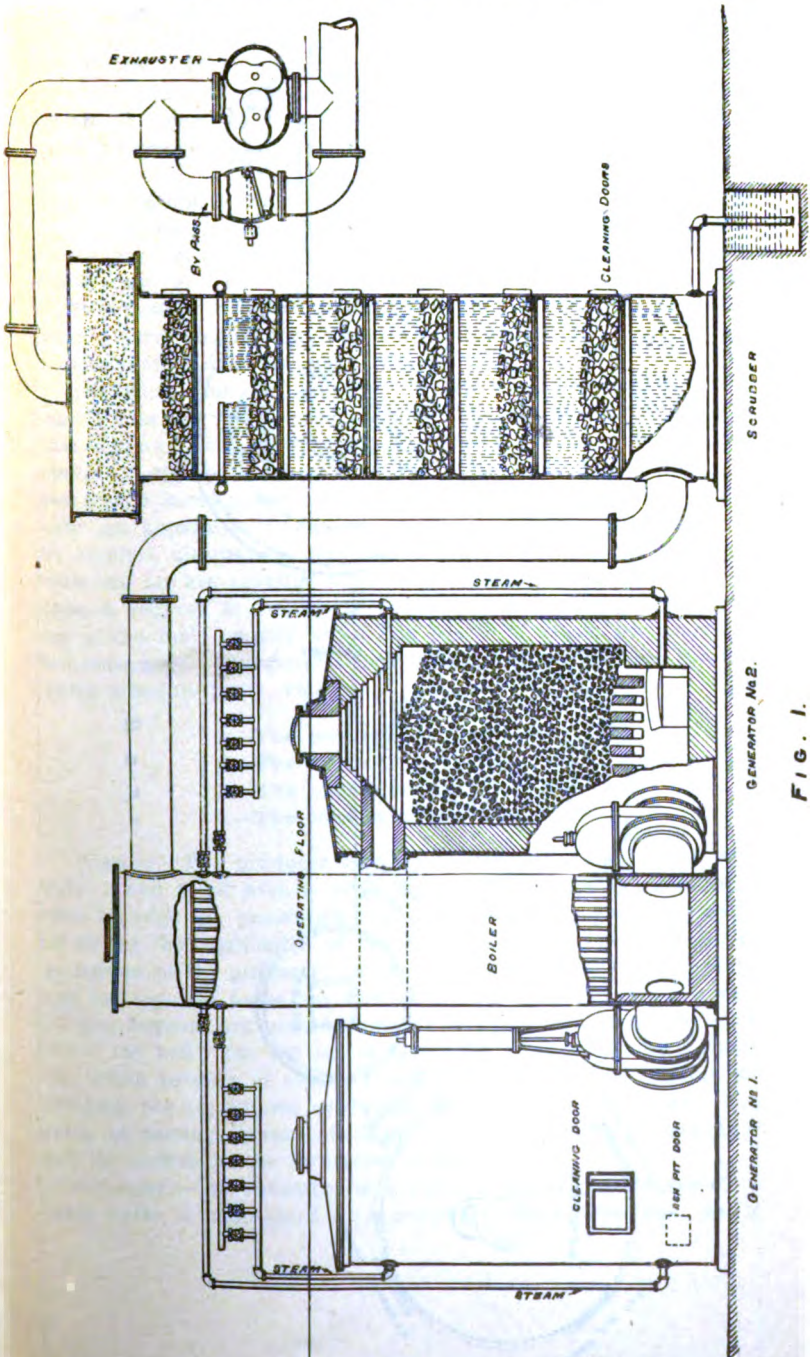

FIG. 1.

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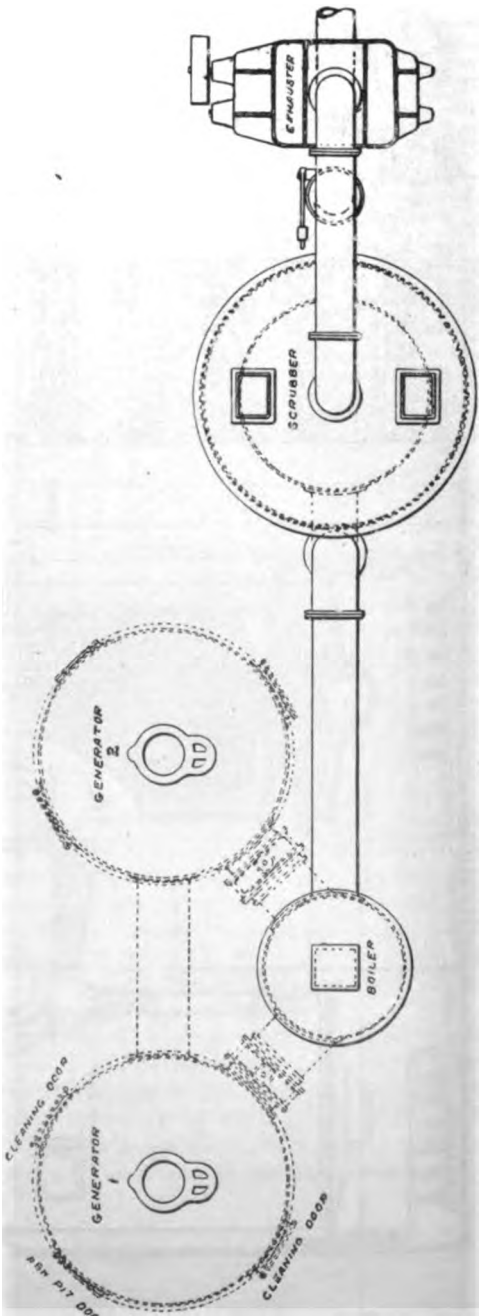

FIG. 2.

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large proportion of their heat for the production of steam to be used under generators for decomposition.

The great advantage of the double generators is that as all the gas is made to pass through the fire, the tarry matter from the coal is converted into fixed gases that can be conducted any distance through ordinary pipes, and at any temperature or pressure.

In operation, a plant, such as I have described, will produce about three volumes of producer gas to one of water gas. The production per ton of bituminous coal is about 35,000 to 45,000 cubic feet of water gas, and 100,000 to 150,000 cubic feet of producer gas.

This system is, however, more especially adapted to large power plants, and, except under special conditions, is of greater capacity than is required for small units.

Semi-Water Gas.—In order to produce a cheap apparatus for small plants, extensive experiments have been made, resulting in what is known as the semi-water gas producer. Since then a large number of different makes have been placed on the market, in sizes from 8 horse power and upwards. This is an evolution of the water gas apparatus, i.e., in the water gas plant, steam and air are supplied alternately, whereas in the semi-water plant, the steam and air are supplied at the same time, and the amount of steam so reduced in volume as not to interfere with the temperature of the fuel (usually about one pound of steam per pound of fuel consumed). The general form of apparatus comprises the following principle parts, viz.:—

1.—The producer, or generator.
2.—The saturator.
3.—The hydraulic box.
4.—The coke scrubber.

Producer.—The producer is a cylindrical steel shell lined with firebrick and fitted with a revolving grate. There is an annular space between the brickwork and the outer shell, through which the air for the combustion of the fuel passes from the saturator to the bottom of the producer. A central collecting bell is suspended from the top and keeps the fuel at a uniform level. One or two charging hoppers are provided, either in the centre or one on each side of the bell. The bottom of the producer is closed by a water seal, which permits of cleaning and removal of ashes without interruping the continuous operation of the plant. The air and steam, in passing upward through the incandescent fuel combines with the carbon in the formation of gas.

Saturator.—The saturator is a water jacketed pipe or vessel in which water is maintained at a constant level. The gas, as it

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passes from the producer, is hot; the saturator not only reduces the temperature, but the entering air in its passage through the saturator on its way to the bottom of the producer, comes in contact with the heated water, and picks up a certain amount of steam vapour, which on its course through the fire increases the calorific value of the gas there being formed.

In some cases the separate saturator is dispensed with and an evaporator attached to the top of the producer which supplies the necessary steam.

Hydraulic Box.—From the saturator the gas passes to the hydraulic box, which acts as a seal and prevents the gas from backing up into the producer. It is provided with an inclined water trough which permits the removal of accumulated dust; the gas then enteres the coke scrubber.

Coke Scrubber.—This is a cylindrical steel shell filled with coke through which a small quantity of water trickles. The gas is here cleaned of any tarry products it may contain, and is cooled to atmospheric temperature, and finally, before reaching the engine, the gas passes through the sawdust scrubber.

Sawdust Scrubber.—This is fitted with trays filled with sawdust or other similar material which exposes the gas to a very large surface, and removes the last vestige of fine ash or other solid matter which may have been carried over.

Under some circumstances the sawdust scrubber is not necessary, the gas being sufficiently clean after leaving the coke scrubber for engine use.

Starting.—To start the plant a small hand blower is used, the fire is started in the generator, and coal added. The atmospheric valve is opened, and the blower used until the fuel becomes incandescent, and in a condition to give off gas (which usually takes from 10 to 15 minutes) when the atmospheric valve is closed and the gas allowed to pass through the apparatus. The engine is then started, and the production of the gas becomes automatic; the suction stroke of the engine furnishes the draft through the fuel and draws sufficient air and steam to combine with the carbon to keep up the supply of gas.

Fuel.—the fuel most suitable for consumption in the semi-water gas producer is anthracite, owing to its freedom from sulphur, smoke and other impurities, and the product of a ton of coal is about 160,000 cubic feet of gas.

Of the different kinds of gas here mentioned, the illuminating gas is by far the richest, or highest in heat units, containing about 600 heat units per cubic foot.

The second in point of calorific value is the water gas, containing about 300 heat units per cubic foot.

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The third is semi-water gas, containing about 150 heat units per cubic foot.

And the lowest in calorific value is the producer gas, containing about 110 heat units per cubic foot. This latter is due to the fact that the gas is obtained by a combination of oxygen and carbon, but to get the required volume of oxygen, we have to introduce four times the volume of nitrogen (as air is composed of one-fifth oxygen and four-fifths nitrogen) thereby producing a very weak or lean gas, as nitrogen has no value in heat energy.

The principle upon which the producer operates is, that limiting the amount of air or oxygen admitted to the fuel to one half what would be required for complete combustion, or 1.33 pounds per pound of carbon, carbonic oxide gas is formed instead of carbonic acid gas (the latter being a product of complete combustion). As the steam passing through the incandescent bed of fuel is disintegrated, the oxygen combining with the carbon and the hydrogen remaining in the gas, very much improves its quality; owing to its high heat value and the quantity of air necessary being reduced and to the oxygen obtained from the disintegration of the steam, the nitrogen is reduced in like ratio.

In semi-water gas the heat value is increased to about 150 B.T.U. per cubic foot, and in straight water gas about 300 B.T.U. per cubic foot.

Illuminating gas, owing to its being made in air-tight retorts, is almost entirely free from nitrogen.

The following table gives an approximate percentage of the principal constituents of the four different kinds of gas:—

	Illuminating.	Water.	Semi-Water	Producer.
Carbonic oxide..	5.7	42	25	23
Hydrogen..	46.5	48	19	2
Carbonic acid	3.1	6	6	3.6
Nitrogen.	3.7	5	49	63.5
Marsh Gas	35.7			7.4
Heat units, approx.	600	300	150	110

Relative power developed with various qualities of gas is shown in diagram, Fig. 4, in which semi-water gas at 150 B.T.U is taken as standard.

Producer gas of	110	B.T.U.	= 90 H.P.
Semi-water gas of	150	"	=100 H.P.
Water gas of..	300	"	=112 H.P.
Coal gas of	600	"	=117 H.P.

RELATIVE COST OF POWER.

In making a comparison of the costs of the various motive powers, to simplify the matter we will consider the question of

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fuel only, except in the case of illuminating gas, which we can only consider at its cost ($1.00) per 1,000 cubic feet.

Gasoline.—The consumption of gasoline in a gasoline engine is one-eighth of a gallon per B.H.P. hour. This at 20 cents per gallon will figure out as follows:—

.125 x 10 x 312 = 390 gallons @ 20 cents = $78.00 per B.H.P. per annum.

Illuminating Gas with the Modern Gas Engine.—A B.H.P. can be produced with from 14 to 16 cubic feet of illuminating gas, or, an average of 15 feet per hour. This would figure out as follows:—

15 x 10 (hours per day) = 150 x 312 (days per year) = 46,800 cubic feet @ $1.00 = $46.80 per annum per B.H.P.

Steam.—The average automatic high pressure engine of small powers requires from four to eight pounds of coal per hour per B.H.P., take the average six pounds; this figures out as follows:

6 x 10 (hours per day) x 312 = 18,720 lbs. @ $4.00 per ton = $37.44 per B.H.P. per annum.

Semi-Water Gas from Anthracite Coal.—The most reputable gas engine builders will guarantee their engines to develop a B.H.P. on one pound of coal in the generator; this will figure out as follows:—

1 x 10 x 312 = 3,120 lbs. of coal, $5.00 per ton = $7.80 per B.H.P. per annum.

Semi-Water Gas, from Gas Coke.—The author has recently obtained a copy of a test of an electric power plant of about 80 H.P. The fuel was common gas coke and the consumption was .92 lbs. per hour per B.H.P.; this figures out as follows:—

.92 x 10 x 312 = 2,870 lbs. of coke @ $4.00 = $5.74 per B.H.P. per annum.

Water Gas.—With large gas plants of 500 H.P. and over, the Crossley Bros. can produce a B.H.P. on .80 lb. of bituminous coal per B.H.P.; this would figure out as follows:—

.80 x 10 x 312 = 2,870 lbs. of bituminous coal @ $4.00 = $5.00 per B.H.P. per annum.

Summary.

Cost of Power from Various Motives per B.H.P. per Annum.

Power from gasoline	$78.00
" " illuminating gas	46.80
" " steam engine	37.44
" " semi-water gas (anthracite coal)	7.80
" " semi-water gas (common gas coke)	5.74
" " water and producer gas (bituminous coal)	5.00

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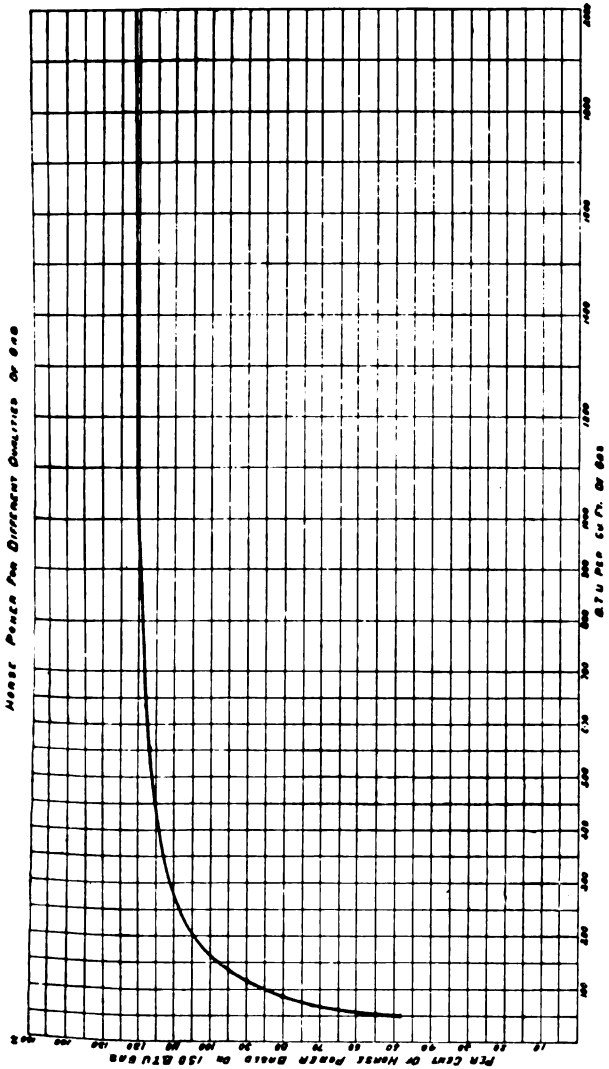

FIG. 4.

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From the foregoing it will be seen that the gas engine with a suitable gas producer will generate power at a lower rate of cost than any other source of power, although it is only within the last few years that it has been brought to its present high efficiency. Increased sizes and higher compressions are the most marked features in its recent development. These changes have necessitated material modifications of design.

Strains, due to increased heat, and higher pressures, made the operation of the large valves and the older designs an impossibility, therefore, new devices were necessary to overcome the new requirements.

Figures 6, letters A., B. and C. show the cylinder end of large engines as now made by Crossley Bros., showing improvements in the mode of constructing the main casting, water jacketed exhaust valve and cylinders. From these it will be seen that the exhaust valve box is now a separate casting, thus removing one of the main causes of fractured breech ends, which was one of the chief causes of trouble with large engines. There is no part exposed to the hot working fluids which has not got water on the other side, with the exception of the head of the inlet valve, which is kept cool by the admission of each fresh charge. This is the only satisfactory method of preventing pre-ignition, which is much more liable to occur with gases of high calorific value, containing a large percentage of hydrogen, such as illuminating gas, water gas and semi-water gas.

"The use of large engines for driving directly coupled dynamos for various purposes is rapidly coming into practice both on the continent and in the United States. In some cases, when used for special purposes, large engines are running night and day on their full output; this, of course, means a most severe test of every part of the engine; a year's run on such duty being, at least, equal to three years' ordinary work, and in one case an engine of 400 H.P. ran seven months continuously without being stopped. And there are a number of instances of large engines running 97% of the total hours of the year, the 3% including stoppages due to all causes, either affecting the engine or the electrical part of the combination."

"The requirements of the electricians for steadiness in running and accurate governing, have now got far beyond anything anticipated some years ago."

For great accuracy in the governing of large engines of the "Otto," or four stroke type, it is desirable to use four cylinders in any suitable combination, and an impulse automatically regulated by the governor; such an engine, if properly constructed, will give almost perfect regulation. In two engines tested by Mr. James

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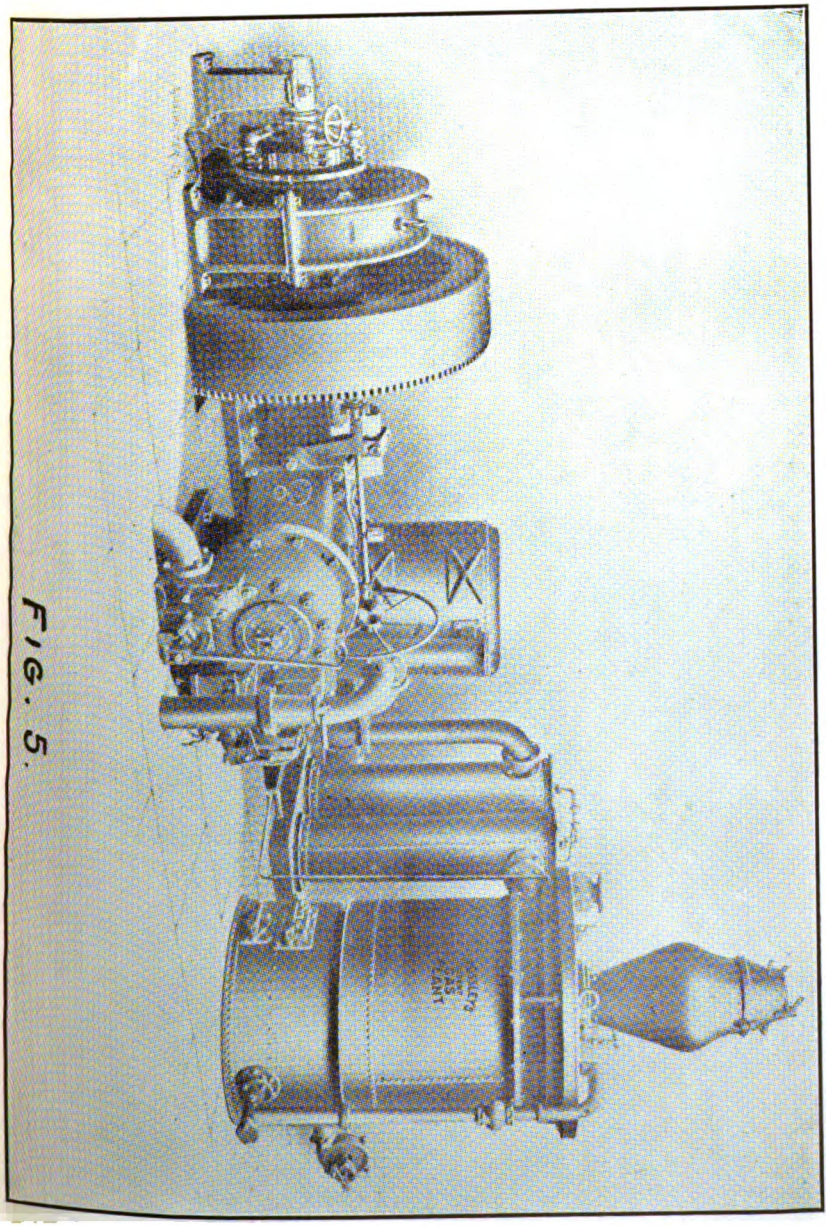

FIG. 5.

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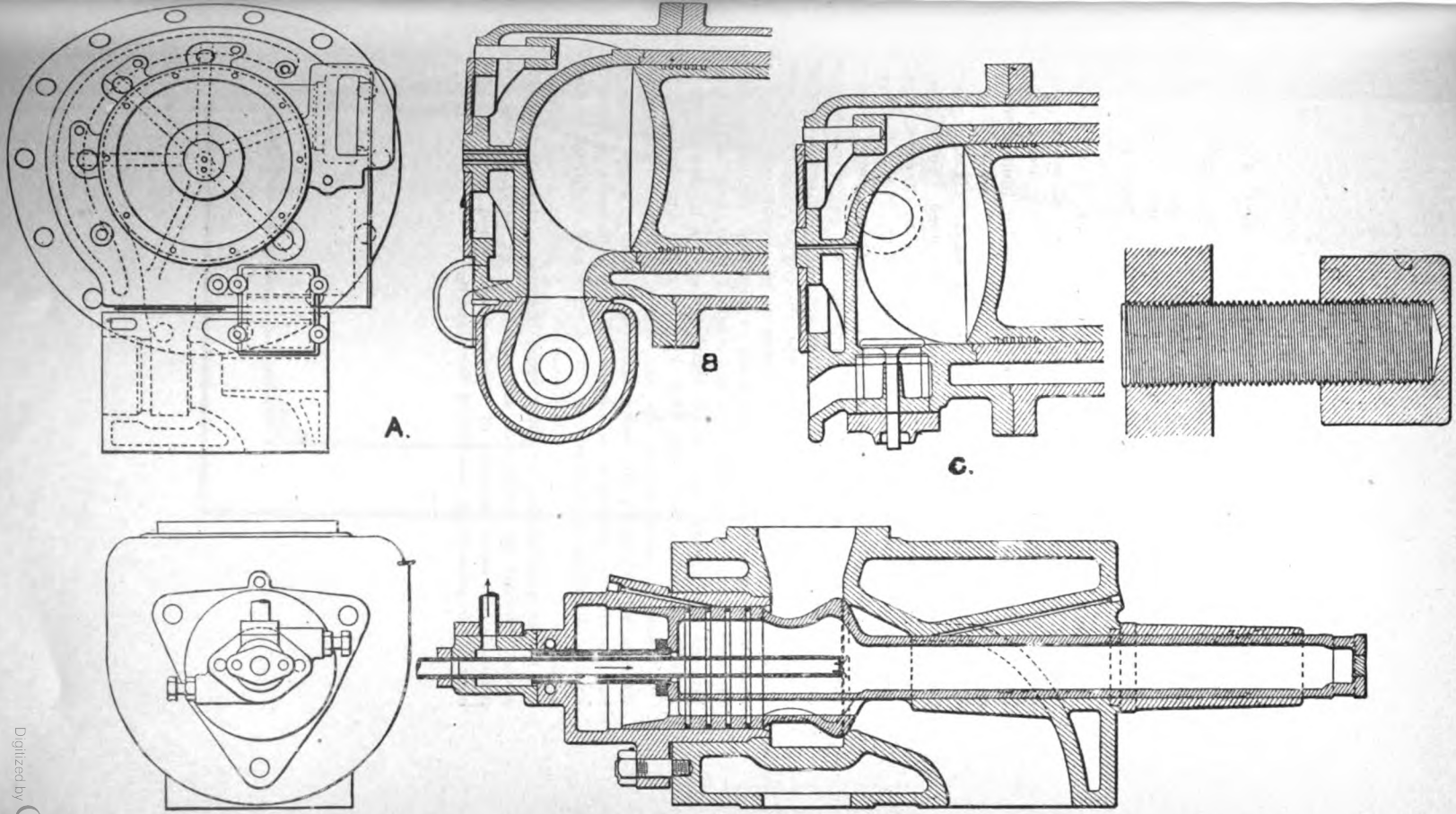

Fig. 6.

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Atkinson, M.I.C.E., the variation between full load and no load, was three-fourths of one per cent.

Ignition.—The hot tube ignition has proven the more satisfactory, and when suitable gas is available, it is impossible to improve on it for stationary engines. Hot metal tubes have, however, almost entirely disappeared, and long life porcelain tubes taken their place.

"When two tubes are fitted to an engine, each with its own chimney and flame, its own separate ignition valve and gear, with means of shutting off either to replace a burst tube without stopping, it looks as if there were not much room for improvement in this direction."

There are numerous instances when a suitable gas supply is not available, and electric ignition has to be used. For this purpose, unless a constant supply of electricity is to be had, small dynamo machines are considered the best.

For the lighting of large dwellings, or other buildings, where there is no power used for other purposes, the use of gas engines for operating an electric generator is not only cheaper in running expenses than the steam engine, but the comparison holds good for the lighting of towns and villages at the usual cost of gas to consumers; but when the generation of producer gas can be made for such use on the premises of the electric plant, and by the same persons who operate the electric plant, the saving in cost of electric lighting is several fold less than by direct gas burning.

When the mere fact of the cost of gas for direct lighting, and its cost for producing the same light by its use in a gas engine to run an electric generator is considered, the difference in favor of electric lighting in preference to direct gas lighting is most apparent.

It has been known for some years that for a given light power, about one-half the volume of gas consumed in direct lighting will produce the same amount of candle power when used in a gas engine for generating electricity for lighting.

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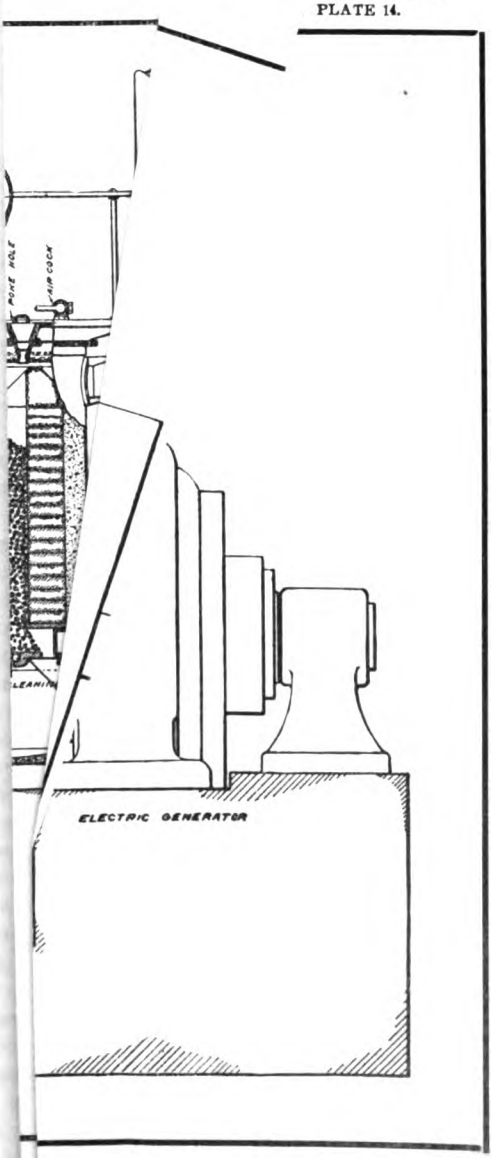
PLATE 14.



Mr. Ashcroft.

Mr. Laurie.

Mr. Goldmark.

Mr. Laurie.

Mr. Durley.

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DISCUSSION.

Mr. Ashcroft asked as to the relative cost of steam and gas engine installation. It appeared to him that Mr Laurie compared the cost of gas in one case with the cost of the engine in the other. Mr. Ashcroft.

Mr. Laurie replied that in the case of the ordinary steam plant, the gas engine would figure 30 to 35% higher, but if the latest improvements were adopted for a steam plant, the cost would be about the same. It was very difficult to make close comparisons, as conditions were so varied. Mr. Laurie.

Mr. Henry Goldmark asked what disposition had been made of the producer gas in this comparison with water gas. Mr. Goldmark.

Mr. Laurie replied that the water gas was taken in the abstract. The producer gas would not figure out more than 100 to 110. Sometimes, as in this case, the two were mixed in one gasometer. Mr. Laurie.

Mr. R. J. Durley said that at the end of the paper the author referred to the method of ignition used in modern gas engines, and said that on the whole, hot tube ignition had been found to be the most satisfactory. That was not altogether in accordance with his experience, and he wished to ask Mr. Laurie whether it was not a fact that in many large engines which were being built at the present time, electric ignition had been found very satisfactory. His experience, so far as it went, had been that electric ignition was more satisfactory from one point of view, inasmuch as weak mixtures could be ignited very readily. There was likely to be trouble with hot tube ignition when weak mixtures were encountered. The costs which Mr. Laurie had given were fuel costs only, and would require some modification, taking into account labor, etc., and all the other charges which had to be met. He also wished to ask whether these figures were not for test runs. He would like to emphasize the difference between figures which could be obtained for a steam plant or a gas engine, for a run of a week or ten days, and the figures for permanent running. He did not want to minimize the economy of gas engines, but he did not think it was quite so great as would appear from the figures which were based on short runs. The gas engines had one considerable advantage. In the case of a plant standing ready for use, the stand-by losses were not nearly so great as in the case of the steam plant. Another advantage which the gas plant undoubtedly had over the steam plant, unless the latter was fitted with all the latest type of equipment, was that Mr. Durley.

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Mr. Durley. it had not so great a load factor. In some figures, which showed in an installation of considerable size, say 2,000 h.p., the consumption of anthracite coal on a run of considerable length was about 2.2 lbs. per K. W. hour, the cost of fuel running on a 25% load factor was approximately 25%. There were very few steam plants which could make so good a showing. There were one or two points in connection with the economy of gas engines which Mr. Laurie had not had space to show. One of them was the question of economy in the production of the steam necessary for water gas purposes. Of course, in most cases a separate boiler and producer were employed, but now efforts were being made to use the exhaust gases to generate the steam required by the producers, and there was no reason why this should not be done, that is, the supply of heat was ample for the purpose, and in large plants a very considerable saving might be effected in that way. Another source of economy which existed in England, was the by-products. They had a marketable value which reduced very materially the cost of coal consumption. He would like to hear whether Mr. Laurie was in possession of any figures which would bear out these facts.

Mr. Laurie. Mr. Laurie replied that in the modern system of gas producing, some of the plants were arranged to make use of the by-products, but in the case of small plants which were built for commercial purposes, it would make it much more complicated and expensive. In reference to the boiler for steam producing for generators, it was mentioned that the waste heat from the generators gave all the heat required. There would be no fuel required for the boilers. Of course the boilers were only used for the large plants, over 500 h.p.; for small producer plants there was no necessity for the boiler. In reference to ignition, where producer gases were used, unless illuminating gas was to be had, electrical ignition was preferable, but in so far as the hot tube ignition was concerned, he understood one of the largest concerns in the Old Country was using it exclusively.

Mr. Goldmark. Mr. Henry Goldmark said he did not profess any special knowledge on the subject under discussion, but had considered the question of using gas in connection with the C.P.R. shops. In the Angus shops a good many boilers were required in any case, to heat the buildings, and this finally induced the C.P.R. to rule out gas for use in prime movers. But after it was decided not to utilize gas engines instead of steam engines, the question came up again in connection with the furnaces in the boiler shops. There were many furnaces which could be operated by coal, or gas, or oil, and a number of propositions were received from manufacturers of gas apparatus. The idea was, in a general way, very

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much like the one outlined here, by which water gases would be supplied for the furnaces, and at the same time there would be set free a considerable quantity of producer gases which would not be used in the furnaces, but which could be used in gas engines. The installation of gas engines as an auxiliary to the steam engines, to take care of the peaks, was therefore considered. Mr. McHenry, at that time chief engineer, was very much interested, and went into the matter very thoroughly. It was ultimately decided not to adopt gas, as the first cost of apparatus proved to be very high, and it was seen that under the conditions it would be much more economical to take the gas and burn it under the boilers than to install gas engines. Of course it was realized that the gas would be much more efficient in the engines than under the boilers, but cost considered, it was very much better to use the gas under the boilers. The total cost of the plant would, however, have been very great—in fact, over $200,000—simply to provide gas for the blacksmith purposes, so that oil furnaces were ultimately adopted, which, according to Mr. Toltz, gave better results, taking everything into consideration. Mr. Goldmark.

Mr. E. G. M. Cape remarked that the figures which Mr. Laurie had given of the comparative costs per h.p. per annum, were very interesting, but perhaps discriminated somewhat in favor of gas plants. In his item for steam power, Mr. Laurie had taken an average coal consumption of 6 lbs per h.p. per hour. With an evaporation of 8 lbs. of water per lb. of coal, this would be the same thing as requiring 48 lbs. of steam per h.p. per hour. Of course in a steam power plant of any size, a much better result than this would be expected. With compound engines worked under 200 lbs. pressume and 15 degrees super-heat, and a vacuum of 28", it was possible to develop one horse power per hour, with, say 14 lbs. of steam. Mr. Cape.

A great thing to be said in favor of steam power in a country like Canada was that large quantities of steam were required in the ordinary plant for heating purposes, and this steam, which had to be produced for seven months of the year, no matter what the power requirements might be, could be used in the steam engines before being put into the heating system; in this way the steam was used twice. Thus either heat costs nothing, or power costs nothing during the winter months.

In heating factories or shops, it was often found that the steam requirements for power very nearly balanced with the requirements for heating. This was the case in a plant which we had in mind, where turbines are used to supply the power. The guaranteed consumption per K.W. hour of these machines was 43.8 lbs. of steam

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Mr. Cape. non-condensing, and 19.8 lbs. with twenty-eight inches of vacuum, the steam in both cases being supplied with pressure of 160 lbs. and 150° Fahrenheit super-heat. The plant was so arranged that one or both of the turbines could run either condensing or exhausting direct into the heating system.

Mr. Laurie. Mr. W. H. Laurie answered that in reference to steam consumption, he had referred in the comparison to small powers. The best test of a high pressure steam engine 20" cylinder by 42" stroke, was 3½ lbs. per indicated h.p. Indicated h.p. and brake h.p. were quite different. The estimated average brake h.p. was 4 lbs., which was a very fair figure since not half the engines in the city were running at 8 lbs. That was for small power, from 5 to 75 H.P. and did not refer to high power engines and large plants having all the latest improvements, because they were not used in the city.

Mr. Ashcroft. Mr. G. B. Ashcroft said he knew of one gas engine plant which had been in operation in Montreal for something over a year. It was a 25 H.P. plant, gas producer, using anthracite coal. The firm was using it for power, and also had a 6 K.W. generator and used it for light. It took about one half of a man's time for labour divided fairly evenly between the engine and the producer. They used city gas and tube ignition, the city gas being used for starting. In the morning, when it was started up, city gas was used until the producer was in working order. In the winter they ran the engine to its full capacity. It used about 250 lbs. of coal per day, practically 1 lb. per H.P. Figuring 10% for interest and depreciation, would bring the power to $31.30 per H.P. per annum. The plant had been in operation for more than a year.

Mr. Durley. Mr. R. J. Durley remarked that the figures did not give very much information, since the load was not known. The costs estimated that the plant ran ten hours per day, 25 days per month, but the H.P. was not stated. Unless there was some information regarding the load factor, the cost was perhaps misleading.

Mr. Doyle. Mr. S. G. Doyle, introduced by Mr. Ashcroft, took part in the discussion. He said that in his opinion, gas power as typified in the gas engines and gas plants supplied by the best European manufacturers, was, next to water power, the cheapest form of power in existence. Some engineers doubted whether the gas engine could be relied upon to give its rated power continuously, and under the various fluctuations of load such as were experienced in the average central station. This question was very ably dealt with by Mr. Hugh Campbell, M. Inst. M. E., in a paper read before the members of the Institution of Electrical Engineers, Leeds, England, in November last. Mr. Campbell proved from the behaviour of the gas

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engines in the central stations at Walthamstow, Redditch, North- Mr. Doyle.
wich, Guernsey and Hebden Bridge, that gas engines could now be relied upon to give results under all working conditions, equal, if not superior to, the results obtained from the best of steam engines, whilst in economy they left the steam driven stations far behind.

He quite agreed with Professor Durley that in discussing the relative economies of gas and steam engines, test or trial runs extending over a short period only should be ignored. The figures relating to the works cost to produce power at the Guernsey Electricity Corporation's steam driven central station, and also the costs at their gas driven station, where they have in operation two Campbell gas engines, each of 300 B.H.P., showed a difference in favor of gas engines in some cases of over one cent per unit generated. These figures included fuel, wages, water, stores, repairs, etc, and were very complete, covering a period of six months of actual working.

Another Campbell engine, of 60 B.H.P., operating pumps at the waterworks, Combe-Down, Bath, and carrying an overload almost all the time, was, according to Mr. Owen Bayldon, the engineer in charge, running on an average 130 hours per week, with a coal consumption of only 34 cwt. The steam plant which preceded the gas engines used from 11 to 13 tons to do the same work.

With regard to the question of ignition, he could hardly agree with Mr. Laurie that the hot tube was the best system. It was a good system where rich coal gas was available, but even then, if the governing of the engine affected at all the quality of the mixture, the hot tube was scarcely reliable. Personally, if he were putting in engines, say for driving alternators in parallel, or for any purpose where missfires were likely to prove a serious let down, he would be inclined to duplicate the igniting apparatus; in the case of using coal gas by putting both hot tube and electric ignition, and where producer gas was used, by a double system of electric ignition.

With regard to the heating question which had been raised in connection with the application of gas engines in this country, he thought the seriousness of the heating problem was often over-estimated, and at all events the manufacturer who put in gas power was scarcely worse off than the manufacturer who bought electric power from a power corporation, and for central station work sufficient heat could easily be obtained from the exhaust gases to keep the largest of stations up to the required temperature.

Another feature of the application of gas power had been almost entirely overlooked, although it was of no mean importance, namely the entire absence of smoke where gas power was used.

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Mr. Doyle. The very latest and best thing that had come to his notice in the way of gas engines was a 4 cylinder vertical engine of 350 B.H.P. where the balance of the parts had been brought as near perfection as was possible to get in any moving mass. Messrs. Campbell, the manufacturers, claimed that under average working conditions this engine had practically no cyclical variations, and the momentary variation in speed between full load and no load obtained by pulling out the main switch on the board, was less than 5%, the permanent variations being almost nil.

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GENERAL SECTION.

At the meeting of the section held on Thursday. April 20th, 1905, Mr. Duncan MacPherson in the chair, the following papers were read:—

PAPER No. 227.

THE CONSTRUCTION OF A TIMBER DRY DOCK.

By G. B. ASHCROFT, A. M. Can. Soc. C. E.

INTRODUCTION.

Among the pages of the Engineering News for Nov. 28th, 1901, there appeared the following brief note:—"The William Skinner Ship-Building & Dry Dock Co., of Baltimore, Md., formally opened the second largest dry-dock in this country on Nov. 25. The dock is built of timber carried on pile work and the entrance is granite masonry backed by concrete. The steel caisson-gate gives an opening 80 ft. wide at the top with 22½ ft. of water over the sill. The general dimensions of the dock are as follows: Length over all 628 ft., length on keel blocks, 600 ft., width of entrance at the bottom, 60 ft., at top, 80 ft., width of dock on the floor, 62 ft., width at coping, 125 ft., depth of water over sill at low water, 22½ ft."

The same journal in its issue of Jan. 9th, 1901 devoted one page to a more extended notice of this work.

In the present paper it is proposed to give a more detailed account of this dock as it actually is; the methods of construction employed; the contract prices, quantities of material and cost data; a comparison of this with the other large docks to be found along the eastern coast of North America; and in conclusion, to show what three years of operation has done to verify the judgment of the designers and builders in their solution of the various engineering problems which were presented to them.

GENERAL DESCRIPTION.

The ship-building plant of the Wm. Skinner & Sons Co., is located at the foot of East Cross St., in Baltimore, Md. At the

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time of building the new dry dock, this plant consisted of several work shops equipped with compressed air machinery, and a marine railway for the docking of small vessels.

The port of Baltimore could boast of several such plants and in addition a timber dry-dock of small size, constructed some 20 years ago and at this time in a bad state of repair.

The size and tonnage of the larger vessels entering this port had long since exceeded the limits of its docking facilities, and whenever repairs were needed upon such ships they were compelled to seek the larger docks at Newport News, or New York.

The "William Skinner & Sons Ship-Building & Dry Dock Co, of Baltimore Md.," was organized. The newly organized company then secured additional property adjoining that of the old company, and had plans prepared for a modern timber dry dock of large dimensions. The proposed site of the new dock was covered by old brick warehouses and an old pier. It was impossible to secure sufficient property so that the proposed dock could be constructed within the then existing shore line, and it was therefore necessary to plan for building the entrance and about 175 ft., of the dock body, in the open waters of the harbor. The average rise and fall of the tides at this point is about 18 inches, though the maximum has been known to greatly exceed this amount, when both tide and wind are favorable for extreme conditions. The water is brackish.

Borings were made to ascertain the probable character of the foundations, and soundings taken in the harbor, after which the plans and specifications were prepared by Messrs. Ritchie & Ruple, Consulting Engineers of Cleveland, O. As finally agreed upon, the plans called for a dock body built of timber, supported upon piles, an entrance composed of concrete faced with granite masonry, and a steel caisson gate.

The work was divided into four parts as regards the letting of contracts as follows: 1st. Dredging and removing the old structures and piers. 2nd. Construction of the protection bulkheads and cofferdam. 3rd. Construction of the concrete and masonry of the entrance and power house foundations. 4th. Construction of the timber work and the main body of the dock.

A contract was signed on June 30th, 1899, with the Delaware Construction Co., of Wilmington, Del., covering all the work in parts 1 to 4, and they commenced operations a few days later. The mechanical equipment, the caisson gate and the superstructure of the power house were arranged for by special contracts to be noted later.

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Detailed Description.

Foundations.

The nature of the soil upon which the dock was built varied considerably, as shown by the materials encountered during construction. In excavating one of the bulkheads, after the river mud had been removed, there followed a layer of yellow clay some 8 or 10 inches in thickness; a few inches of vegetable matter resembling peat; a stratum 4 feet thick, composed of coarse quartzite pebbles and fine red sand merging into densely compacted layers of pure sand; and beneath all extending to some undetermined depth, a pure white clay. Before water had reached it, this clay was exceedingly hard, would take on some polish when rubbed, and was sometimes used by the carpenters to chalk lines. After standing some time in contact with water it became softer, resembling somewhat the texture of castile soap.

The concrete work about the dock entrance was in all cases placed directly upon this clay. It is doubtful if any of the piles or sheet piles ever penetrated this material to any extent. In fact those of the temporary work which were afterward pulled, appeared as if they had landed upon a rock, and the whiteness of their points was evidence enough as to what they had landed upon. No actual rock was however, encountered at any point.

Protection Work.

The safety and efficiency of a timber dry dock depends in a large measure upon the possibility of keeping water away from the piles and foundations. In the work under consideration this was a very important matter, for as has been mentioned above, over 200 feet of the structure was situated in the waters of the harbor.

It was proposed to surround the entire dock, (excepting of course the entrance way) with a single line of sheet piling. Commencing back some 65 feet from the shore line and extending outward to the limits of the dock, this line was to be doubled, the two lines being spaced 16 ft., apart. Round piles of yellow pine were driven every ten ft. upon the outer sides of these were drift-bolted two parallel lines of 12 by 12 inch Southern pine waling strips. One strip being placed at the level of the bulkhead top, and the other below low water line. The lower waling strip was omitted from the sheet piling within the shore lines.

Timber braces, 12 by 12 inch Southern pine were placed across this bulkhead at every pair of the guide piles and a 1¾ inch iron

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tie-rod beside each brace. The piles were slightly notched to keep the braces in position.

Along these guide wales was driven a continuous wall of Southern pine sheet piles, tongue and grooved, and mostly 40 feet in length. The sheet piles were 10 by 12 inches with a white pine tongue 4 inches square. Each pile was secured to the waling strips by ⅞ inch machine bolts.

Between the outer ends of these permanent bulkheads, a temporary one of like character was driven, which formed the cofferdam, and two single lines of temporary sheet piles were driven from bulkhead to bulkhead, enclosing that portion destined to be excavated for the entrance foundations, and the pump well.

Entrance.

The entrance proper of the dock, is concrete foundations and backing, faced with heavy granite masonry. The outer apron is 12 feet wide, the middle apron 12, and the inner 20 ft., The surface of each is level with the exception of the inner, which for a distance of 12 feet slopes downward to the cross drain in the main body of the dock.

The entire surface is bush-hammered to a smooth finish. The sills, two in number, rise vertically from the aprons a height of 18 inches. The minimum width of entrance at the top of the inner sill is 60 ft.

The granite abutments are rock faced, with the exception of the bush-hammered jambs. They rise vertically from the inner sill level a height of 29 feet and recede 10, thus making the width of entrance at the coping level, 80 feet.

Each stone in course is doweled to the stones below, with two iron pins, each 1 inch square and 4 inches long.

Beneath the aprons are 11 steel bands, 10 by ½ inch, by 22 feet, bent upward at the ends, which serve to bind the sill stones together.

Behind the north abutment, the concrete backing is carried in a solid mass to the protection bulkhead, and in the concrete backing behind the south abutment, are formed the pump well, and engine pit, and drainage tunnel from the main dock body.

Gate.

When the dock is in use the entrance is closed by a steel caisson gate whose general dimensions and construction are shown upon the drawings accompanying this paper and the two photographs here shown.

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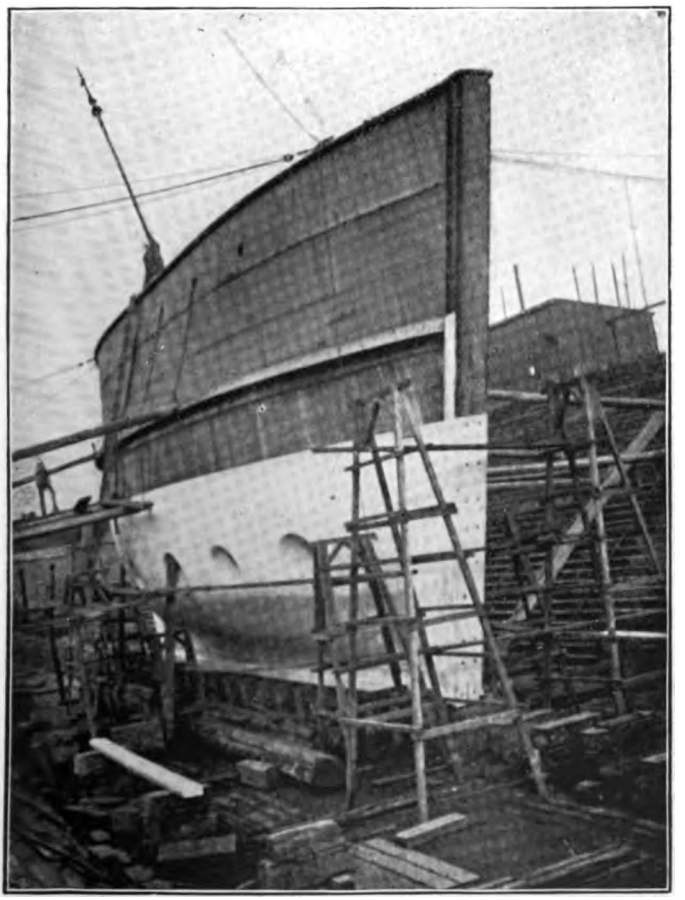

THE CAISSON-GATE (COMPLETED).

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The material specified was medium, open hearth, acid steel, testing from 54 to 62,000 pounds in tension, per sq. in., and containing not more than .08% of phosphorus and not more than .04% of sulphur.

A 4″ by 12″ oak strip is fastened along each face of the keel, stem and stern posts, to which is attached a 10″ by ½″ gum gasket. It carries a permanent ballast of concrete.

For filling the dock, it is provided with six 36″ valves, and for water ballast, four 6″ valves and one 8″ centrifugal pump with steam engine. Steam is supplied from the boilers in the main power house.

The gate draws 13′-8″ of water when carrying only permanent ballast, and at such times its displacement is 212 tons. It was built under special contract, by the Spedden Ship Building Co., of Baltimore.

Main Body of the Dock.

The bottom of the dock is supported by 13 longitudinal rows of 20 ft., piles. The five center rows are spaced 4 ft. c. to c. longitudinally and 3 ft., c. to c. transversely. Upon these comes more directly the weight upon the keel blocks. The other 8 rows are spaced 8 ft., c. to c. longitudinally and transversely as shown on the "Half Midship Section" on the drawings. The sides of the dock are supported by rows of 25, 30, 35 and 40 ft., piles, spaced 4 and 8 ft., on centers. The piles are capped by 12″ by 12″ yellow pine timbers, secured to each pile with 1″ by 20″ drift bolts. The main cross timbers are spaced 8 ft., c. to c. They consist of Oregon (Douglas) Fir, 16″ by 18″ by 70′ in length. Midway between each of these on the center line of the dock, is a similar piece, 14 ft., in length. They are secured to the pile capping with 1″ by 30″ drift bolts. Along the sides of the cross timbers are spiked 4″ by 10″ floor joists, and from the ends of the 14 ft. cross timbers, 6″ by 10″ floor joists extend to the foot of the side slopes. Upon these is spiked a flooring of 4″ white oak plank. The first 80 feet of dock floor adjacent to the entrance and the last 40 next the head, is on a level with the tops of the cross timbers. The balance is 4″ below the level at the center line and slopes uniformly toward the sides, on a grade of 3″ in 30 ft. The floor rises toward the head of the dock on a grade of 6″ per hundred feet. The slope timbers are spaced 4 ft., c. to c., being alternately 12″ by 14″ and 8″ by 14″ yellow pine timber. They are framed into the cross timbers at the bottom of the slopes, and secured to the slope pile capping by ⅞″ machine bolts. The yellow pine altars were cut from a timber 10″ by 14″, so that when placed in position they would have a rise and tread of ten inches.

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They are secured to the slope timbers by 12 inch boat spikes, and abutting ends are doweled with 1 inch by 6 inch iron pins. They are laid with the treads horizontal, which causes the lowest course to disappear about every 170 feet, owing to the rise in the dock floor.

Four chutes are provided on each side for the delivery of material. At these points the altars are omitted and 6 inch oak plank spiked upon the slope timbers.

Across the ends of the long floor timbers and along the piles in the slope rows are placed 6 by 12 inch yellow pine waling strips, bolted to the piles with ⅞ inch machine bolts. Between these waling strips are placed 12 by 12 inch braces, making a continuous line of bracing from the outer row of piles to the foot of the slopes. Another 12 by 12 inch brace extends from the waling on the outer row of piles to the capping of the third row, and a 1¾ inch iron tie rod is placed beside it. This combination of braces and rod forms a truss as shown on the drawing.

The head of the dock was originally designed to be similar to the sides, that is approximately, a 45 degree slope. During construction, however, an extension was built into this slope, forming a box with vertical sides, thus gaining over 24 ft., in total docking length.

Drainage System.

From the masonry of the entrance to the head of the dock, the floor rises uniformly 6 inches per 100 feet. From the center line to the foot of the side slopes the floor falls uniformly 3 inches in 30 feet. This causes the water to flow toward the sides and entrance of the dock. Along each side the dock, for its entire floor length, extends a drain some 5 feet wide and 3 feet deep, built of 3 inch plank spiked to the piling as shown on the detail drawings.

The oak flooring covers this drain but is not spiked down and the pieces are not fitted so closely together.

Adjacent to the masonry is a 6 foot cross drain, into which the side drains empty. The plains show this to be of a similar plank construction, but as actually constructed, the foundations of the masonry aprons were extended into the body of the dock far enough to build this cross drain in concrete.

From the cross drain, a 6 foot square tunnel formed in the concrete foundations, runs beneath the south masonry abutment to the pump well below the engine pit.

This pump well is 23 feet 9 inches long by 6 feet deep and its roof is composed of a layer of concrete 10 feet 6 inches thick. In

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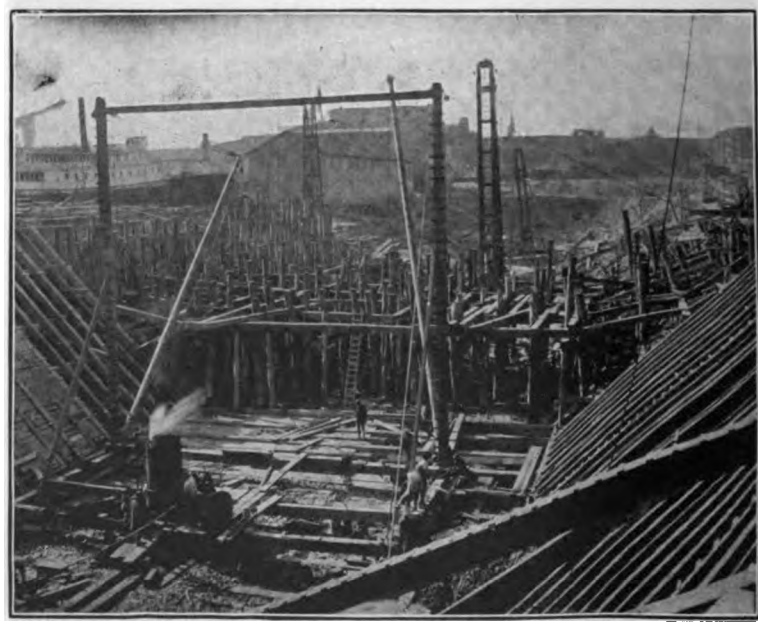
SHEWING CONDITION OF SLOPE PILES, DRIVEN BEFORE DOCK WAS PUMPED OUT. THE SIDES SLID INTO THE DOCK BOTTOM, CARRYING MANY OF THE PILES WITH THEM.



SHEWING FORM OF TRAVELLER USED FOR HANDLING HEAVY TIMBERS.

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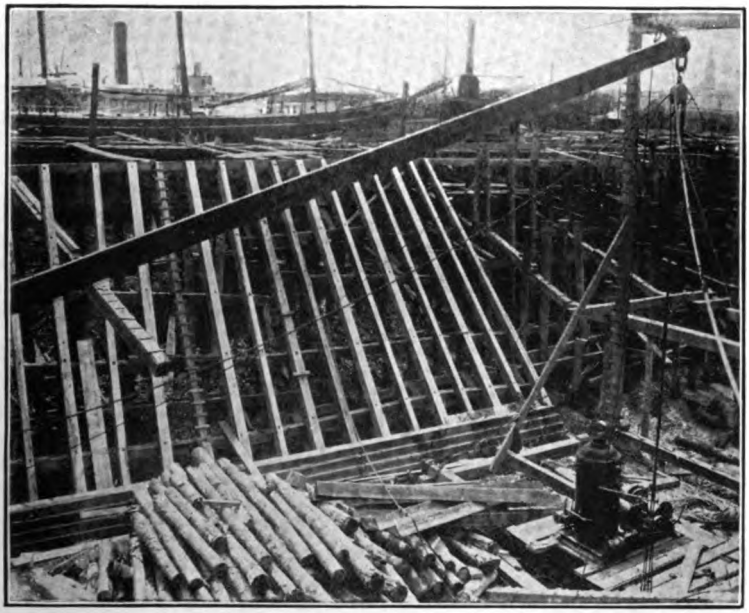

SHEWING THE SIDE SLOPE TIMBERING.

SHEWING FEET OF PILES, DRIVEN FROM TEMPORARY BRACING, BEFORE EXCAVATION HAD BEEN COMPLETED TO POINT OF CUT OFF.

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its centre is a 6 foot square pier to which run 12 inch I-beams from the side walls, as a support to the concrete roof and the machinery. Into this well extend the suction pipes from the centrifugal pumps.

Mechanical Equipment.

For the emptying of the dock there are provided three 36 inch, double suction, centrifugal pumps, directly connected to simple, vertical, non-condensing engines. To take care of the leakage during use, an additional centrifugal pump, with 12 inch discharge, is connected to a small vertical simple engine. This machinery is located in a "pit" formed in the concrete which backs up the south abutment. The floor of this pit is 22 feet below the level of the top of the dock, or 15 feet 6 inches below mean low water line. From each of the large pumps, two 28 inch suction pipes pass vertically downward through the 10 feet 6 inches of concrete into the pump well below. There is one 42 inch, horizontal discharge pipe for each pump.

Steam is supplied from the boiler house at 125 lbs pressure. Three 350 H.P. Heine Safety Water Tube boilers, an auxiliary vertical boiler, two fire pumps, and fan and engine for forcing the draft, complete the equipment of the boiler house.

On actual test after completion, the average efficiency of each main pump was 38,250 gallons per minute. The indicated horse-power of the engines varied from 185 at starting to about 300 at the finish, giving an average efficiency for the pumps of 58%. The maximum efficiency noted at any time during the test was 72½%. These pumps and engines were built and installed by the Morris Machine Works of Baldwinsville, N.Y.

Construction.

General Scheme.

Broadly speaking the proposed plan of operation was as follows: After clearing off the existing structures and old wharves, to dredge away the material to the approximate lines of the dock bottom and side slopes; to drive the permanent protection work while this dredging was in progress; to drive the temporary cofferdam across the ends of the bulkheads, immediately the dredging was completed; to pump out the water and mud from the basin thus enclosed; to drive a line of 20′ permanent sheet piles along the outer and inner face of the aprons; to further excavate within this box to the white clay stratum and upon it start the concrete foundations for the masonry; to build the masonry abutments, pump well, engine pit, powerhouse and main body of the dock.

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This plan was modified considerably as will appear from the description to follow.

Contracts were signed in June 1899, and the contractors went to work almost immediately. By the following Spring the dock site had been cleared and dredged out to the required lines, and the permanent protection work finished, except that portion about the head of the dock which was never completed. This will be noted later when we come to consider the changes made from the original plans, when constructing the head of the dock.

The temporary cofferdam was driven into place and the basin was then ready for pumping out. Meanwhile a pile driving machine, mounted upon a scow, had been floating about within the enclosure and driving the outer row of slope piles along both sides of the dock. Why these piles were driven at this time is not quite clear to the writer, unless it was thought that they could be driven more easily then, than by using a land machine at a later period, or possibly because there was nothing else for the machine to do for the time being.

Afterward when the dock basin was pumped out, most of these piles slid into the bottom of the dock, along with the side slopes, or bent so far out of correct line that it was necessary to pull them out or saw them off and drive others. This gave rise to "extra" claims on the part of the Contractor, who maintained that having once driven them to the lines given by the Engineer, any necessary redriving should be paid for as extra work. If the writer's memory serves him correctly, the original driving was done under protest from the field Inspector, and the claims for extras were never entertained.

Pumping out the enclosure began. As the water level within sank a few feet, those portions of the permanent bulkheads extending beyond the original shore line, started inward toward the center of the basin, crowding before them the undredged slopes and the piles which had just been driven.

Pumping was hastily discontinued and the basin permitted to fill to the level of the water outside. The floating pile driving rig mentioned above, which had been left inside, then drove more piles, upon which were placed the 70 foot Oregon Fir floor timbers, so as to form a transverse set of bracing from bulkhead to bulkhead across the dock. This system of bracing was continued shoreward, at 20 foot intervals, as far as any motion of the bulkheads had been noticed or could be expected. Then, where it had been planned to drive 20 foot sheet piles along the faces of the aprons (as mentioned above), after the dock should have been pumped out, the water machine drove rows of 34 foot piles, thus

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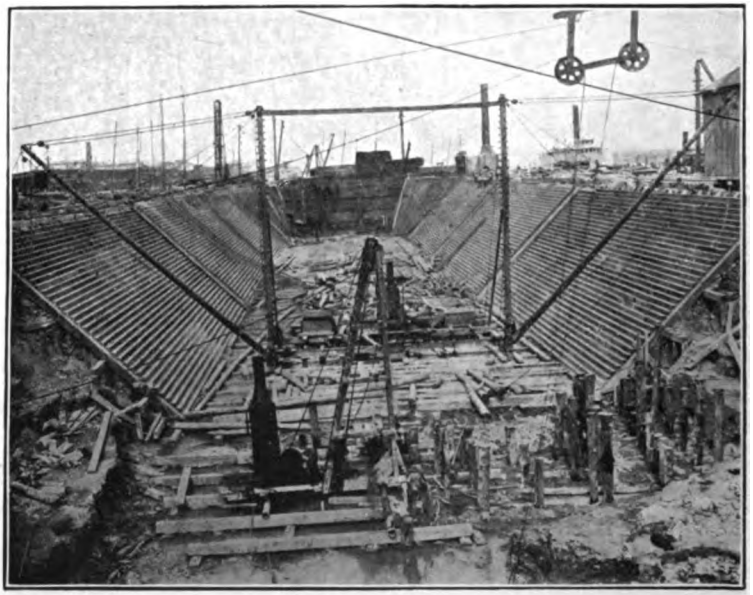
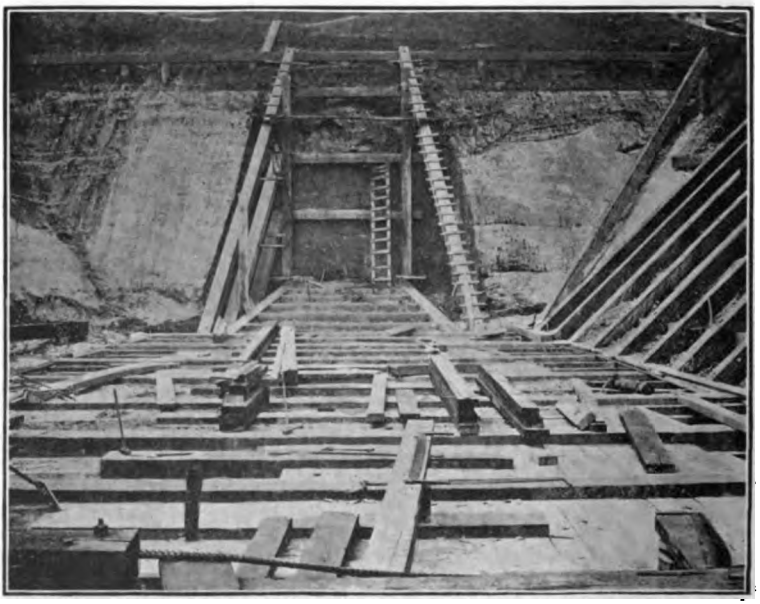


SHEWING CONDITION OF WORK AFTER REACHING PERMANENT SHORE LINE.



SHEWING CONDITION OF FOUNDATION AT HEAD OF DOCK, WHERE IT WILL BE NOTICED THAT THE SOIL STANDS A VERTICAL CUT.

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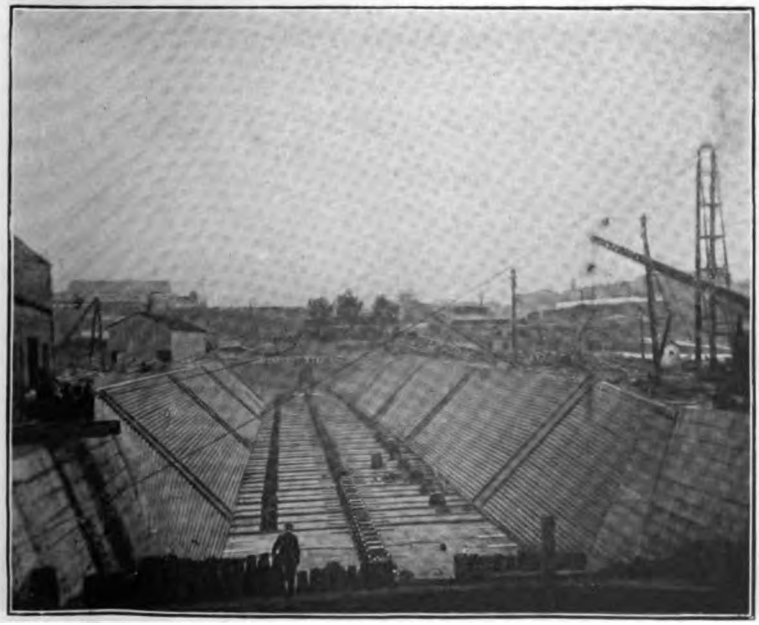
SHEWING THE BOX PROJECTION IN THE HEAD OF THE DOCK.



SHEWING MAIN BODY OF THE DOCK LOOKING FROM THE COFFERDAM.

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preventing what material was left about the foot of the cofferdam from moving into the dock.

Pumping was again started and continued until the bottom of the basin was laid bare. A small centrifugal pump and later a pulsometer, took care of the leakage, which was noticeably greater at high tides.

Entrance.

Excavation.

Within the box like enclosure formed by the bulkheads and the two rows of 34 foot sheet piles, excavation was started for the foundations of the masonry work and the engine pit. The more material removed, the greater became the need of temporary bracing to keep the sides of this box from collapsing. Complete sets of bracing were placed in position for every 6 or 8 feet of excavated depth and as the 12 by 14 and 8 by 14 inch slope timbers were used for this work it was important that they should be cut as little as possible.

Each set placed made it more difficult to place the next below, until the time came when the long timbers could not be landed in horizontal positions and had to be placed wherever a suitable opening could be found.

So thickly were these timbers placed, that at the time the first sill stones were lowered into the pit, there was but one opening to be found of size sufficient to admit them.

Excavation was carried to the stratum of hard white clay. In doing this it was found that the sheet pile protection had not penetrated this clay to any appreciable depth, as in many cases the excavation laid bare the points of the piles. More bracing was the order of the day, and that immediately.

Leaks at high tide had always necessitated regular pumping, but now the water began to find its way down the sides of the sheet piles and through the gravel stratum at their points, in quantities that became alarming. The original idea of driving a stop water cut off wall of 20 feet sheet piles along the front and rear edges of the pit was abandoned, as no pile could be forced into this hard layer of white clay. As a substitute measure a trench some 2 ft. wide and 4 ft. deep was dug in the clay parallel to the face of and at some distance in front of the outer sill of the aprons. This trench was filled with concrete which joined to the concrete foundation, formed a stop water as effective as the piles would have been.

Concreting was started near the middle of the pit and the foundations raised several feet high. This was extended to within

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a few feet of the north bulkhead where the most serious leaks occured under the feet of the piles. At low tides these leaks were temporarily stopped, by driving inch boards along the outsides of the piles and dumping dredged material from the harbor into the bulkhead. Concrete was hurriedly placed along the feet of the piles and raised to the same level as that of the foundations previously placed. No further leakage of a serious nature was experienced in this direction. The concrete was then brought to the finished level of the lowest masonry course by removing the temporary braces as fast as a sufficient quantity of concrete could be placed about the bottom of the piles, to withstand the inward pressure.

Concrete.

The following extracts from the Specifications relating to the concrete work are noted. "One part of cement, two parts of sand and five parts of broken stone, to be throughly mixed, either by hand or suitable machinery, before being put in place, using only enought water to slightly moisten the mass. The several ingredients must be accurately measured for each and every batch of concrete, using suitable rectangular boxes holding not less than three cubic feet each." "The cement used for concrete and mortar shall be a high grade of American Portland, uniform in quality, show good results by ordinary pat tests in air and in hot and cold water, (especially as to changes in volume), and be so finely ground, that at least 93% will pass through a sieve of 80 meshes to the inch, and 89% through a sieve of 100 meshes." "The cement must be slow setting and must not take on an initial set in less than 30 minutes; final set in not less than 3 and more than 6 hours." "Briquettes of neat cement must show a minimum tensile strength as follows: Samples kept in air one day and in water six days, 450 lbs per sq. in.; samples kept in air one day and in water 28 days, 575 lbs per sq. in." "Briquettes of 1 part cement and 2 parts sand, must show a minimum tensile strength as follows: Samples kept in air 1 day and in water 6 days, 150 lbs per sq. in. samples kept in air 1 day and in water 28 days, 200 lbs per sq. in." "Samples will be taken from each lot of 100 bbls. to be selected by the Engineer."

"Sand must be clean, coarse and sharp, free from loam or earth matter, and screened or washed if required." "The stone used for concrete must be broken into pieces as nearly cubical as possible, and not more than 2½" in its longest dimensions; it must be kept free from dirt and rubbish of all kinds, and just before being used must be drenched with water." "Granite is to be preferred for this material."

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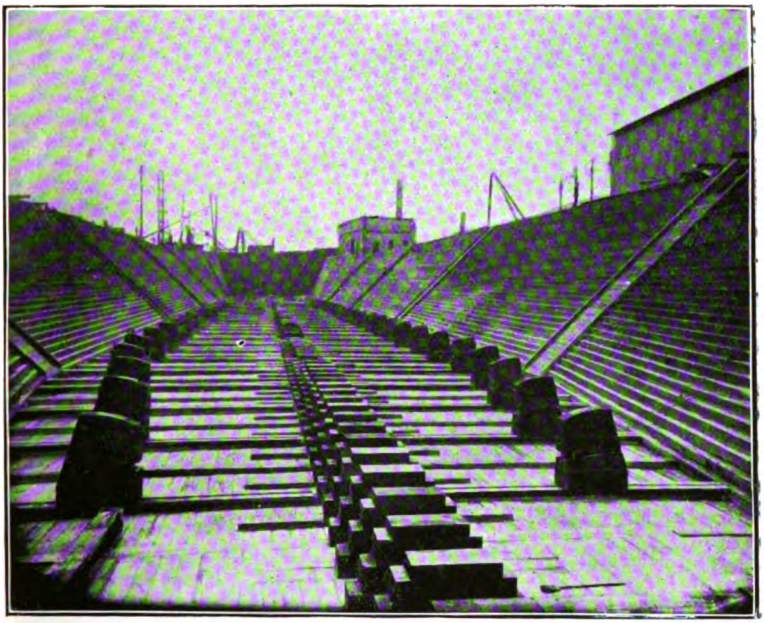

SHEWING MAIN BODY OF DOCK LOOKING FROM BOX IN THE HEAD.

SHEWING TEMPORARY BRACING REQUIRED IN FOUNDATION PIT.

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The concrete was made in accordance with the specifications, using "Dragon" Portland cement and crushed granite, and was mostly machine mixed. The "machine" was of the gravity type, an invention of a local Engineer, who put it on the work as an experimental trial. The result was considered so satisfactory, that we believe this machine, or one along similar lines, can now be purchased in the open market as a patented invention.

As the accompanying photograph shows, the mixer consists of a light wooden frame work supporting two cone shaped hoppers, one vertically above the other, and above these, four pyramidal hoppers, the combined capacity of which, equalled either of the two cones, and at the top, bins for sand and broken stone.

For work in a pit this machine was exceedingly handy. It could be picked up by a dredge boom and placed in any desired location, and raised as the concrete work reached the lower hopper.

In operation it required the services of four men, two to fill the four upper hoppers, and a man at each of the others to regulate the gates. A scow load of sand and another of broken stone would be hauled along side the bulkhead and from this a bucket dredge would keep the sand and stone bins constantly filled.

The men at the upper hoppers would empty a sack of cement in each, and then by opening gates in the bottom of the bins above, allow the necessary amounts of sand and stone to flow in, marks having been previously made on the sides of the hoppers to show the correct proportion of each of the ingredients. The amount of water found by experience to be necessary, would then be dashed into the hoppers, and the charges allowed to run into the first cone hopper below.

Refilling would begin at the top while the men were caring for the first charge in the lower hoppers. The process was thus continuous, and the product as regards thorough mixing was first class, especially where the mixture was dropped from the lowest hopper directly into barrows. The capacity of a single charge was approximately 25 cubic feet of concrete, when rammed into place. The record for a days run (10 hours) was 110 batches, making about 35 cents as the labor charge for a cubic yard of concrete in place.

Masonry.

Upon a seven foot layer of this concrete as a foundation were erected the masonry aprons and abutments.

The stones were massive foliated granite from quarries near Port Deposit Md. The sill stones, 3 and 6 feet thick, were bound together with steel bands, set on beds of mortar and the joints flushed with Portland cement grout.

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It required careful work to place these 15 ton blocks with their top surface truly level and their bush hammered faces to an exact transit line.

The course stones of the abutments are doweled on the beds with two iron pins, 1 inch square and 4 inches long. For setting the jamb stones a batter board was used which had been obtained from the ship building company who made the gate. Thus the gate and the recesses in the abutments were built to the same pattern, and there could be little chance of a misfit.

Behind the north abutment as the masonry work progressed the concrete backing was filled in solid to the bulkhead. Behind the south abutment, in the concrete backing, was formed the drainage tunnel from the dock, the pump well, and the engine pit.

Tunnel, Pump Well and Engine Pit.

The tunnel from the main dock passes under the corner of the masonry and into the pump well behind the abutment. In cross section it is 6 feet square. At the point of junction with the pump well, a sump pit 6 by 6 feet and 2½ inches deep is constructed in the floor of the tunnel. Into this sump extends the suction pipe from the 12 inch centrifugal pump. It is the lowest point of the drainage system, intended to take care of leakage while the dock is in use. The pump well itself is 6 feet deep and has a floor area of approximately 300 square feet.

In the centre a 6 by 6 foot concrete pedestal serves as a support for the 12 inch I beams which are built into the roof as a support to the weight of the suction pipes, engines and pumps. Above the pump well is 10 feet 6 inches of concrete, which forms the foundation of the engine pit. The heavy suction pipes were supported on wooden blocking while the concrete was being placed about them and the blocking left until the completion of the work.

Anchor bolts for the engine bases were about 7 feet long, set within a length of 4 inch gas piping, with heavy cast iron base plates at the bottom.

After the engines had been aligned these gas pipes were run full of cement grout.

There had been plenty of evidence at hand to conclusively demonstrate that a mixture of 1-2-5 concrete was not water proof when subjected to much hydraulic pressure.

As the roof of the pump well would be, at high tide, some 30 feet below the level of the water outside the dock, or subject to a pressure of some 1900 pounds per square foot, it was necessary to provide some means of preventing water leakage into the engine pit. When the concrete above the pump well had reached a point

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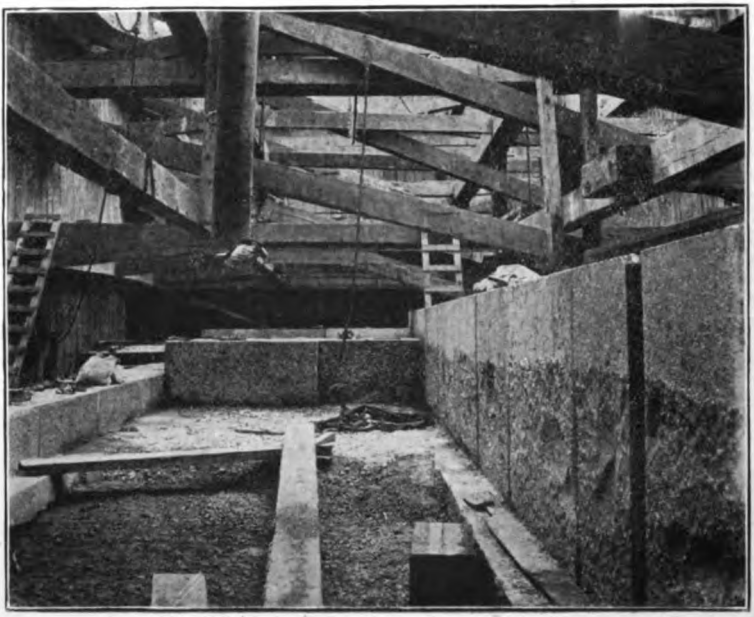
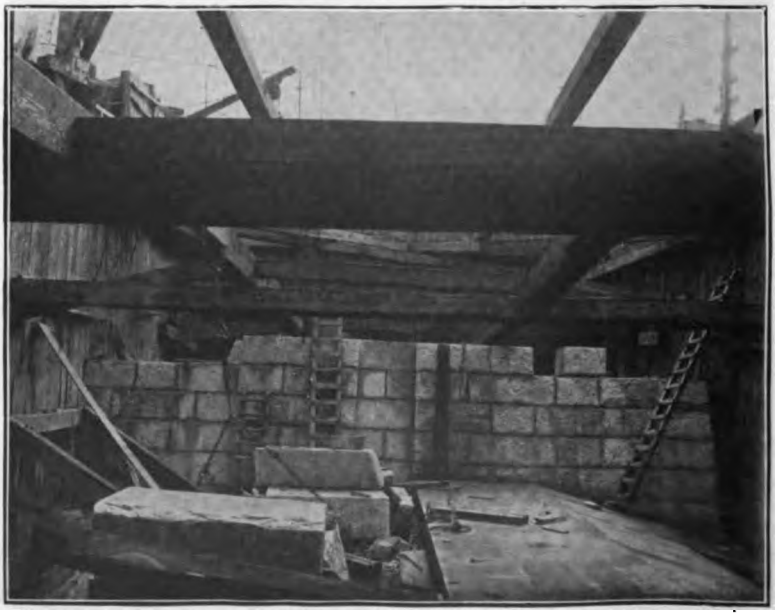


SHEWING THE 6-FOOT INNER SILL STONES AND MIDDLE APRON.



SHEWING INNER SILL, AND APRON WHICH SLOPES TO CROSS DRAIN.

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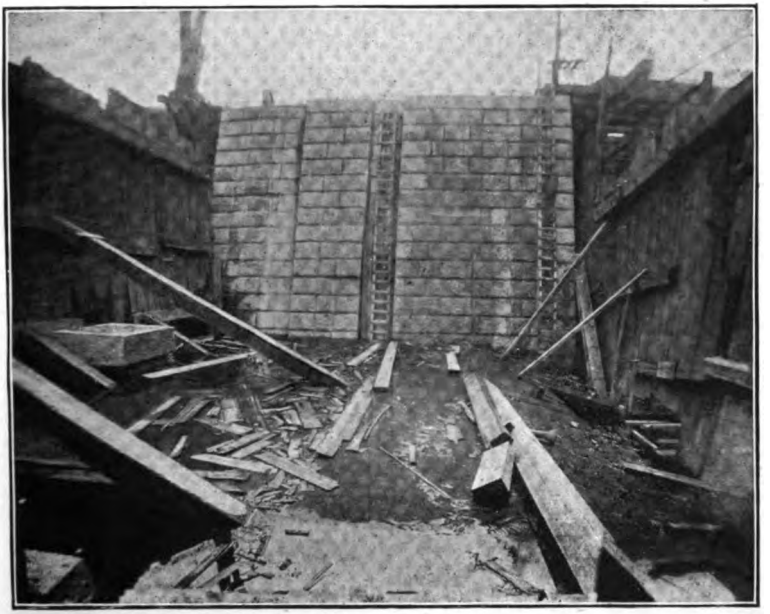
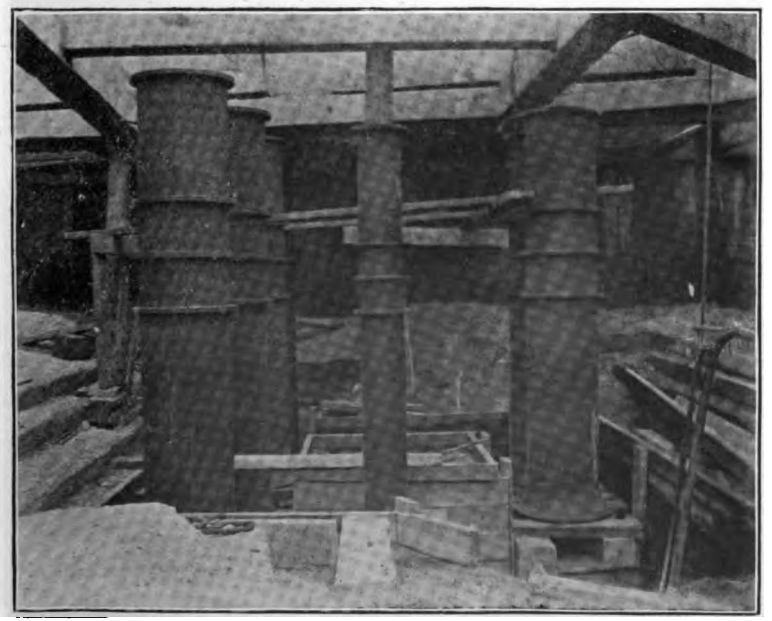


THE COMPLETED ABUTMENT.



SHEWING PUMP WELL, SUCTION PIPES AND PEDESTAL.

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three feet below the finished level of the engine room floor, a 3 inch course of Portland cement mortar (cement 1 part, sand 2 parts) was spread evenly over the surface and extended on all sides a distance of 2 foot 6 inches beyond the finished wall lines of the pit. This 3 inch mortar course was carried up parallel with the walls of the pit to the top of the dock, being back in the concrete 2 feet from the face of the walls. Even with this precaution, the walls appeared to sweat at times, though the moisture did not accumulate in amounts sufficient to run.

This mortar course not having been specified or shown on the original plans became a subject for "extra" charge. It cost in labor and materials a total of $745.00 and the results obtained justified the extra expenidture.

The engine pit is 26 by 42 feet. It is provided at the top with a four foot wide platform, extending around the entire pit, from which stairways lead down to the engines and pumps.

Power House.

The power house is built of brick, set in Rosendale cement mortar. It was constructed under special contract by C. H. Fath & Son of Cleveland, O., for the sum of $5,750.00.

A 13 inch brick wall separates the boiler room from the engine pit, and is continued through the roof. Six, 36 inch steel plate girders, support the roof rafters, which are 2 by 6 inch timbers, spaced 18 inches on centers.

The roof covering is 1¼ inch matched lumber covered with tin. The total floor area figured from the outside dimensions of the stone footing course would be nearly 3274 square ft. which would make the contract cost of the building a little more than $1.75 per square foot of floor area. Figuring the cubic contents from the floor level to the underside of the roof boards, would give approximately 74685 cubic feet, and a contract cost of 7¾ cents per cubic foot.

The writers finds among his notes referring to the power house, that the cubic content of the walls was 7,000 cubic feet, the number of bricks used 116,000, which would give an average of 16½ bricks per cubic. foot.

That portion of power house covering the boilers is located within the lines of the main dock. For the foundations of this and the boilers, piles were driven and covered with a grillage of 10 by 12 inch timbers (old sheet piles removed from temporary work) upon which was placed a layer of concrete 9 feet thick. Air ducts were laid in the concrete for the forced draft.

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Sluice Way.

It was originally planned to construct a buried sluice way in the outer end of the south bulkhead, through which the discharge from the pumps should flow into the harbor. The sluice way is shown on the general plan drawing accompanying this paper, but it was never constructed. Instead, the end of the bulkhead was never closed, and the pumps were allowed to discharge into it.

There was some question as to whether the rush of water from the discharge pipes would not scour out the material from around the feet of the sheet piles, and cause the destruction of the bulkhead. But at present writing, the evidence does not show that such action has taken place to any great extent.

Main Body of Dock.

The necessity of placing the transverse braces to keep the bulkheads in place, materially changed the general scheme of construction, in so far as it applied to the work on the main body of the dock. The presence of these braces made it impossible to use a pile driver on the dock floor level, and by the time work had actually started here, there had accumulated from five to ten feet of mud, gravel and oyster shells in the bottom of the basin.

The pile drivers were placed on run-ways laid on top of these transverse braces, and from this elevation, the piles for the bottom and the side slopes of the first 200 feet of dock length, were driven.

Meanwhile excavation was being completed to the final elevation of pile cut-off, and as fast as a portion could be cleared, the piles would be cut and capped, and the 70 foot cross floor timbers placed in position. The piles driven from the elevation of the temporary braces, shown above, were found to be badly out of line at the point of cut-off, some so badly out, that it was necessary to cut them off a foot lower and cross cap them, in order to obtain any bearing.

The north bulkhead had given such evidence of instability that it was thought inadvisable to trust entirely to the earth back filling for security, so before the temporary bracing had been removed, a mass of concrete was packed in behind the altars and slope timbers, which, starting at the point of the first angle of the dock (80 feet from the abutments), was gradually increased in thickness, until it met the bulkhead some 20 feet back from the masonry, from which point the entire space behind the slopes was filled, until it reached the concrete backing of the masonry.

The cross drain was originally designed to be of plank construction similar in character to the side drains, but was

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constructed in concrete, the foundation work of the aprons being extended into the body of the dock for the purpose.

When sufficient flooring had been placed, a traveller was arranged, which had a derrick on the two forward corners, the booms of which could reach the surface level on either side of the dock. This was used in landing the heavy cross floor timbers and side slopes, and proved to be a very useful affair.

It was originally planned to face the side slope timbers with one inch white pine boards, over which the altars would be spiked, but after facing a small portion, these boards were entirely omitted from the remainder.

Their use necessitated hewing the entire back surface of the altars, in order to keep the front surfaces to the required lines, and it was also thought that these boards would serve to retain water behind the slopes, after the dock had been pumped out, and the gradual drainage of this into the slopes would keep the altars muddy and slippery most of the time.

The soft mud and gravel removed from the bottom of the dock, was placed or rather dropped from buckets behind the slopes, as fast as altars could be placed to retain it. It would have been much preferable to have carried this material entirely away, and provided a better kind. Many times this semi-liquid mass broke through temporary retaining walls and came pouring back on the dock floor. Its use caused a considerable inward bow in the slope timbers at one point, and at another near the first angle in the south side, when the filling had reached nearly to the coping, the pressure was sufficient to force the slope timbers from the piles, and seriously threaten to overturn that portion of the slope. Heavy iron tie rods were immediately placed so as to fasten the slope timbers back to the bulkhead, and the addition of filling was stopped until that portion already placed had entirely dried out.

The north bulkhead at one point for a distance of some fifty feet had crowded so far into the dock that it was within the finished coping line. As it was impossible to get it back again, the top was sawed away and the finishing timbers laid upon it, instead of the pile capping. It seems to have kept to this position ever since, so no harm has resulted from the compromise.

When construction work had progressed to the point where the original shore line was located, the most difficult portion of the work was over. The hydraulic pressure against the bulkheads had no longer to be reckoned with, and the temporary braces having been taken down, a free field was left for the pile drivers and the traveller.

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The drivers were now landed on the dock bottom, and the rows of piles from this point became more satisfactory.

The excavation was mostly in the gravel strata above the white clay, and a number of springs were encountered, which for a time sent water and filling up through the crevices in the flooring, but gradually ceased to flow, or found their way into the lower level of the side drains.

At the extreme head of the dock, however, a very serious spring was encountered, which it was impossible to check. The flow from this source would approximate that from a 5 inch pipe under moderate head. After various attempts to choke it back with concrete and cement, all of which were unsuccessful, the stream was piped into the nearest side drain and allowed to run. This will be referred to a little later, as the owners of the dock, after they came to operate it, tried their hand at controlling this stream.

About the head of the dock, the sand and gravel soil became so compacted that it was practically impossible to drive the slope piles. The top row was driven, after a fashion, however, through the surface soil, and from this point to the foot of the slope, the banks were cut to slope of the side timbers. As the altars were placed, concrete was rammed between them and the bank, in place of earth filling.

It was originally planned to have the head of the dock, a slope, similar to the sides, but this was modified in part, and a box-like projection constructed, which gave an additional 24 feet 2 inches to the effective working length of the dock.

The driving of the protection sheet piling about the head of the dock was abandoned, owing to the hard subsoil, and in its place was constructed a masonry retaining wall, to support the city street which passes close to the head of the dock, but at a higher level.

By this time the keel and bilge blocks had been placed and the dock allowed to slowly fill by leakage. The cofferdam was pulled, and the entrance dredged out to the level of the aprons.

The dock was completed and formally opened on the 25th of November, 1901, thus making the total time of construction a trifle less then 2 years and 3 months. There had been used in the work an amount of material approximately as follows:

Yellow Pine Sheet Piling	1,100,000	ft. B.M.
Yellow Pine Timber	1,028,000	" " "
White Oak Planking	112,000	" " "
White Oak Timber	82,000	" " "

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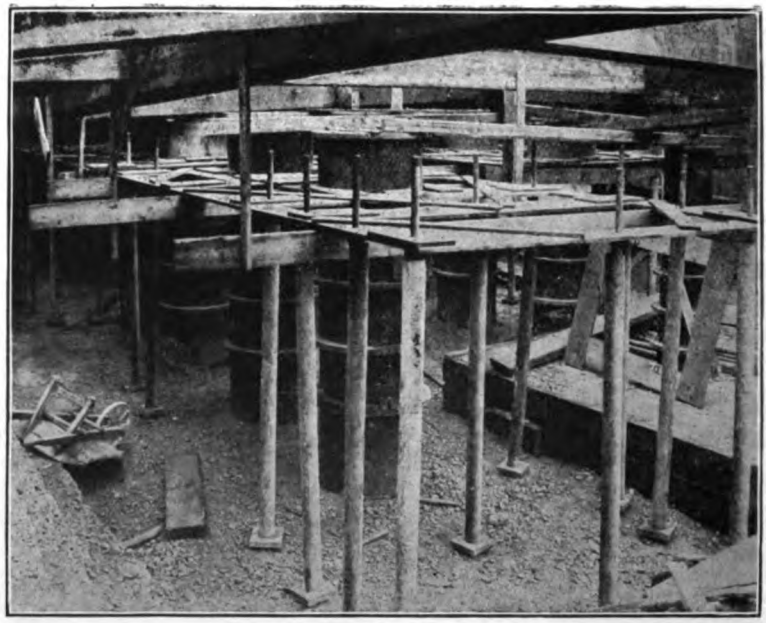

SHEWING METHOD OF SETTING ANCHOR BOLTS FOR ENGINE BASES.

SHEWING COMPLETE SETTING OF SUCTION PIPES AND ANCHOR BOLTS.

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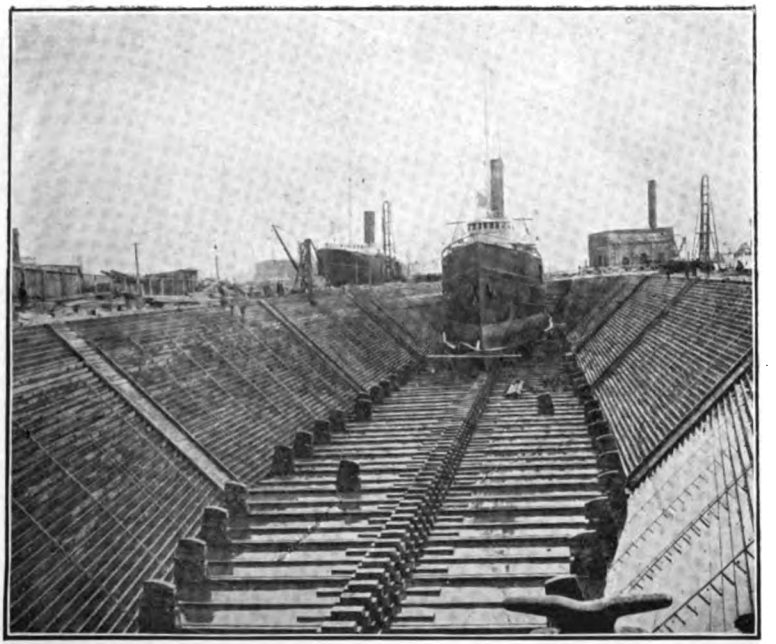
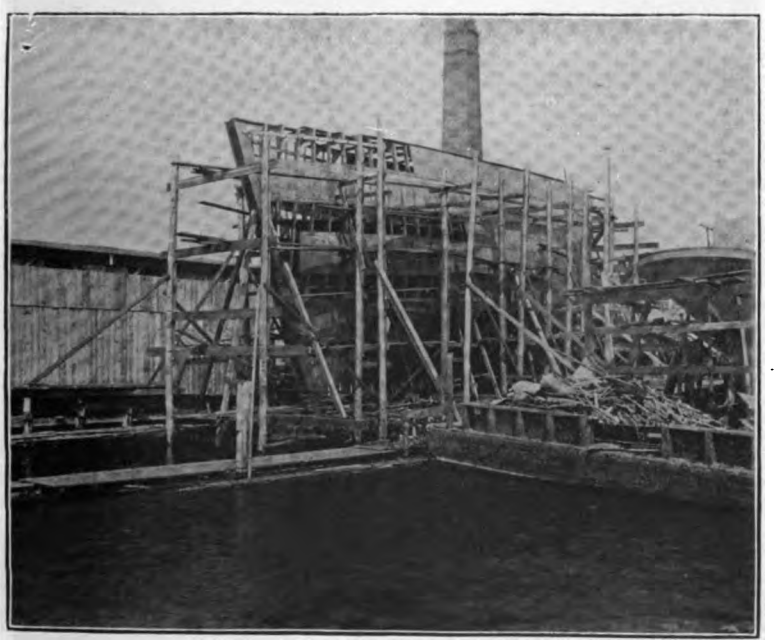


THE FORMAL OPENING, NOVEMBER 25, 1901.
A 300-FOOT STEAMER IN DOCK.



THE CAISSON-GATE (SHEWING CONSTRUCTION).

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Oregon Fir Timber	114,000 ft. B.M.
White Pine Boards	4,600 " " "
Steel Bands	4,100 lbs.
Steel I beams	2,600 "
Iron Tie Rods	52,000 "
Cut Granite Masonry	22,000 cu. ft.
Concrete	180,000 " "
Round Piles	933,000 lin. "

And in addition there had been 30,000 cu. yds., of Excavatfon and 60,000 cu. yds., of Dredging.

COST DATA.

The contract for this work was let on the basis of unit prices for material in place, and labor performed, as per the following schedule:

Dredging	32c.	per cu. yd.
Excavation	37c.	" " "
Sheet Piling	$ 53,25	" ft. B.M.
Yellow Pine Timber	37.60	" " "
White Pine Boards	35.60	" " "
Oregon Fir Timber	26.00	" " "
White Oak Plant	38.00	" " "
Round Piles	15c.	" lin. ft.
Tie Rods	4c.	" lb.
Steel Bands	5c.	" "
I Beams	4 ½ c.	" "
Concrete	21c.	" cu. ft.
Cut Granite	1.09	" " "

The total cost of the complete dock was $430,000.00.

Aside from the carpenter force, which was more or less skilled labor, the working force consisted of negros and foreigners, principally Bohemians. It is the writer's opinion, that the ordinary colored gentlemen, when viewed from the standpoint of reliability as a workman, is a failure. Pay days on this job were twice a month, and after each one, the personnel of the laboring force would contain about 75% of unfamiliar faces. Two weeks steady work was about the limit.

Wages for a ten hour day's work were approximately as follows:

Foremen	$3.50
Carpenters	2.25
Carpenters' Helpers	1.75
Engineers	2.00
Firemen	1.75
Common Laborers	1.50

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The contractor's claims for "extras" on this work reached an enormous total. Unfortunately, in the specifications, no provision had been made for the possible need of temporary bracing. When the protection bulkheads started into the dock, temporary bracing became absolutely necessary, the placing of which the contractor of course claimed to be outside the scope of his contract. A compromise was effected whereby the contractor was to place and remove all needful bracing, using therefor timbers that could later be placed permanently in the dock. For this labor the contractor was to charge extra time, and for the material be allowed a certain percentage of its contract value, until such time as it should be placed in final position in the work.

No one could have foreseen the great amount of time that would be necessary to accomplish this, or the consequent extra cost.

It is seldom that a work of this extent does not cost human life as well as money, and the writer would be pleased were it possible for him to state that this was an exception to the usual rule, but such was not the fact. Two workmen were killed. Of narrow escapes there were several, such as when a pile driver overturned, and a hoisting bucket full of mud fell back among a gang of shovellers. Of the less serious accidents, we might mention that of a member of the Engineering staff, who stepping off a timber one day, found himself up to his shoulders in the rich black ooze at the dock bottom.

Comparison With Other Large Docks.

It may now be of interest to record the finished dimensions of this dry dock, and compare it briefly with the other large structures of similar nature to be found along the North Atlantic seaboard.

In looking over the published literature bearing upon this subject, it is at once evident that there is needed a more systematic method of recording the dimensions of docks, whereby measurements may become directly comparable. One writer in describing a structure will note that "the length on the floor, head to inner abutment is 516 feet" while another states that "extreme length at bottom on keel blocks is 558 feet".

The purpose of a dry dock is to dock vessels, therefore the first principal dimension of a dock, should be given as that of the longest possible boat which the structure would be able to accommodate, or in other words, the greatest horizontal distance, measured along the level of the tops of the keel blocks, from a vertical line tangent to the inner face of the caisson gate, to the corresponding point in the head of the dock. Next in importance is the minimum depth of water over the entrance sills, after which

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CONCRETE MIXER.

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should be given the width of entrance at the level of the top of the highest sill, the vertical distance from the top of this sill to the coping level, and the width of entrance at this level. In the body of the dock, dimensions should be given as follows: Maximum width on floor level and at the level of the top of the keel blocks, maximum width at coping level between the inside faces of the coping timbers, and horizontal distance at coping level from vertical tangent to inner face of caisson to the inner face of the coping timber at the head of the dock.

Following this method, the finished dimensions of the Baltimore dock are as follows:

The horizontal distance at level of keel blocks, from a vertical tangent to the inner side of the caisson, to the vertical face of the box in the head is 599 feet 4 inches. There is over the inner sill at any low tide, 22 feet of water, and at high tide, 25½ feet has been recorded. The width of entrance at the level of the top of the inner sill is 60 feet, and at the coping level, 80 feet. The top of the inner sill is 29 feet below the coping level. The maximum width of dock body is 60 ft. at the floor level, and 69 feet at level of tops of the keel blocks. The maximum width at coping level is 125 ft. between inner faces of the coping timbers. The over all dimension at coping level, from tangent to the caisson, to inner face of coping timbers at the dock head is 604 feet 7 inches.

The other large docks along the Atlantic seaboard are located at the following points: St. Johns, Nfld.; Halifax, N. S.; Portsmouth, N.H.; Boston, Mass.; Brooklyn, N.Y.; League Island, Pa.; Newport News, Va.; Norfolk, Va.; and Port Royal, S.C.

In the following table, the writer has compiled, from various sources, the principal characteristics of these. The indefiniteness of the two leading dimensions will emphasize what has just been stated regarding the desirability of a more uniform system.

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TABLE SHOWING CHARACTERISTICS OF THE PRINCIPAL DRY DOCKS TO BE FOUND ON THE NORTH ATLANTIC SEABOARD.

Location.	Character of the Structure.	Year when Completed.	Time spent in Construction.	Cost.	Length (coping level).	Length (on floor).	Width—body (coping level).	Width—body (floor level).	Width—entrance (coping level).	Width—entrance (sill level).	Depth of Sill below coping level.	Depth of Water over Sill.
St. Johns, Nfld.	Concrete & Timber	1884	2 years	$550,000 *b*	600′ *c*	558′ *k*	132′ 4″	49′ 10″				25′ H.T.
Halifax, N.S.....	Stone and Concrete	1889	3 years	$750,000	600′ *d*	560′ *l*	102′	70′	89′ 6″	81′	34′ 6″	30′ H.T.
Portsmouth, N.H.	Granite & Concrete			$1,089,000 *b*	775 *f*	725′	130′	80′				30′ H.T.
Boston, Mass, No. 1 . . .	Granite	1833	5 years	$677,000	396′ 5″ *g*	367′ 5″ *m*	80′	30′	60′	44′	30′	25′ H.T.
" " No. 2 . .	Granite & Concrete			$1,025,000 *b*	750′ *h*	729′ *h*	114′	72′	101′ 8⅝″		35′ 2″	30′ M. H.W.
Brooklyn, N.Y., No. 1. .	Granite	1851	7 years	$2,241,000	369′ 3″ *g*	333′ 3″ *m*	100′	30′	66′	48′	30′	25′ H.T.
" " No. 2. .	Timber *a*	1890	3 years	$565,892 *b*	500′ *i*		130′ 4″	50′	85′		30′ 6″	
" " No. 3. .	Timber	1897			600′ *h*	556′ *k*	151′	64′	105′	70′	33′	28′ M. H.W.
League Island, Pa.	Timber	1891			500′ *g*	459′ 8″ *m*			85′			25′ 5″ H.T.
Baltimore, Md...	Timber	1901	2 yrs. 3 mo.	$130,000	604′ 7″ *j*	559′ 4″ *n*	125′ *o*	60′	80′	60′	29′	25′ 5″ H.T.
Newport News, Va, No. 1	Timber				638′ 6″ *g*	573′ *m*	130′	49′	96′ 3″	50′		24′ 5″
" " " " No. 2	Timber	1901			860′ 5″ *g*	804′ *m*	162′	80′	114′	84′		30′
Norfolk, Va., No. 1. . . .	Granite	1833		$945,676	331′ 8″ *g*	302′ 8″ *m*	86′	50′	66′	44′	30′	25′ H.T.
" " " 2.....	Timber				500′ *g*	459′ 8″ *m*			85′			25′ 0″ H.T.
Port Royal, S C. ..	Timber	1895	4 years	$418,915 *b*	496′ *o*	459′ *m*			97′			26′ 0″ H.T.

NOTES:

a. Rebuilt in granite and concrete in 1902.
b Contract price.
c. "Head to caisson in outer sill."
d. "Head to outer groove."
e. "Head to gate in outer groove."
f. "Over all."
g. "Extreme length."
h "Head to outer gate sill."
i. "Inside caisson."
j From inner face of caisson, when in outer groove, to inner face of the coping timbers at dock head.
k. "On the keel blocks."
l. "On bottom, head to inner groove."
m. "On bottom."
n. "On the keel blocks from inner face of caisson when in outer groove, to vertical face of box in dock head."
o. Neat width between inner faces of coping timbers.

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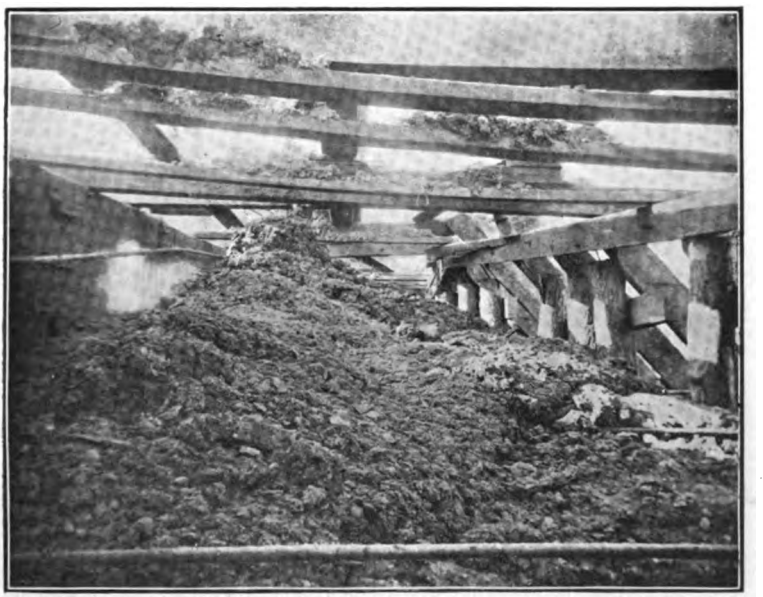

SHEWING RESULT OF PRESSURE, DUE TO SEMI-LIQUID BACKFILLING.

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By a study of the table, it is seen that in maximum length of docking facility, the Baltimore dock is only exceeded by dock number 2 at Newport News, dock number 2 at Boston, and the United States government dock at Portsmouth.

The Portsmouth and Boston docks were still under construction at the time the Baltimore Dock was completed, so that at the time of opening, it could rank as the second largest dock on the coast.

When we consider the serious mishaps that have attended the construction of some of these docks, and the length of time required for their completion, we find that the Baltimore dock was built within a reasonable time, at a not excessive cost, and was practically free from misfortune.

The timber dock at Port Royal was under construction for a period of four years, during which time the cofferdam gave way, the dock floor was lifted by the hydraulic pressure, and the dock was flooded by the tidal wave of August 1893.

Though the contract price given in the table is only $418,915, it has been stated that the dock cost the United States government upwards of one million dollars, including site and repairs, and a recent report states that it is to be abandoned entirely.

In the new Boston dock the cofferdam failed twice during construction, at one time a length of 200 feet giving way, and at another time the dock was flooded and all work stopped, due to a settlement and overflow of the clay banking at the sides.

The two timber docks at Brooklyn have been the cause of many anxious moments on the part of the officials in charge. There has been leaks which were estimated at 10,000 gallons per minute.

Dock number 2, after nine years or so of use, failed so seriously that in 1900 it was almost completely rebuilt in concrete and masonry, and can hardly be classed at this time as a timber dock.

Conclusion.

The Baltimore dock has now been in operation for nearly three and a half years, and it may be of interest, in conclusion, to see what the result has been.

Through the concrete backing and the joints of the granite abutments, at the time of completion, there were several places where small streams of water had found entrance into the dock. It was thought at the time, that these streams of muddy water would gradually deposit enough silt to choke back the flow, but such has not been the case. The leakage through the concrete, remains about the same, no worse than at first and no better.

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The 3 inch mortar course about the engine pit has proved effective. There are several damp places, but at no point can running water be seen, and what dampness there is, shows in horizontal lines around the engine room, and is evidently caused by an incomplete bond between one day's work on this mortar course, and the next.

The concrete placed between the altars and the north bulkhead, has served to keep the bulkhead in place, but at this point there is more leakage through the altars than at others. Since the filling has become compacted, there have been no visible signs of movement either in the bulkheads or the slopes of the basin.

The large stream of water at the head of the dock, (mention of which has been previously made) gave considerable trouble, in that it brought with it quantities of fine sand which choked up the side drains. After various attempts to control it, a test well was drilled, which showed that at a depth of 65 to 80 feet below the coping level, there existed a stratum of coarse gravel, and rock at a depth of 132 feet. Three ten inch pipes were driven to the rock, and perforated where they passed through the gravel stratum.

These wells are pumped by compressed air and the work has to go on constantly whenever the dock is being used.

At the outlet of the pumps, where the sluice way was omitted, there has been no evidence of scour about the feet of the sheet piles. The drainage system has proved of ample size for the work intended.

The shortest time in which the dock has ever been pumped out with all three pumps running, is 70 minutes. With two pumps going, as is usually done, it can be emptied in 90 minutes.

There is no doubt that in the designing and building of this dock, many things would have been done otherwise, could foresight only have been as keen as hindsight. But after all is said and done, can there be a better test of the success of an engineering work, than that it satisfactorily performs the functions for which it was designed?

The writer concludes this paper with the words of the President of the Company, who in a recent letter to the author took occasion to say, "In our three years operating the dock, we have made but one change, and that was to lengthen the smoke stack so as to cut out forced draft, otherwise if I had another dock to build, I would not make any change whatever."

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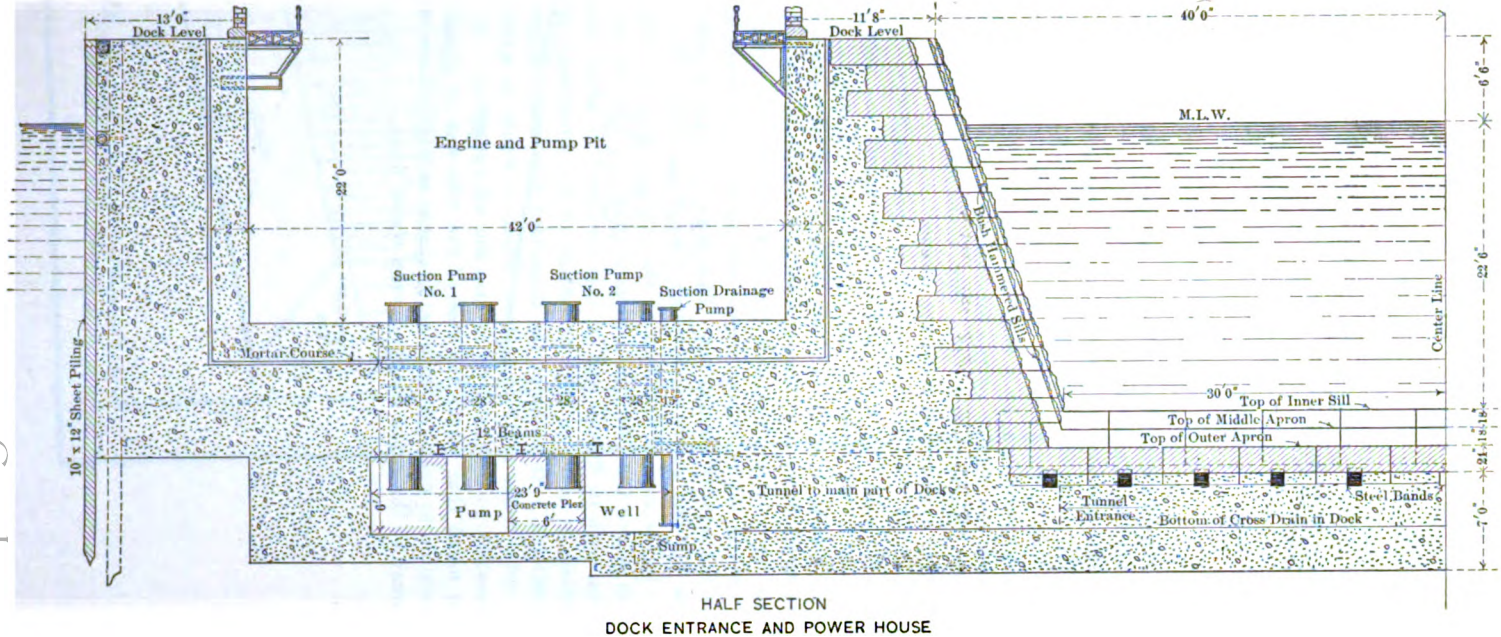
THE WM SKINNER & SONS CO.
BALTIMORE, MD.

DRY DOCK.

SECTION



HALF SECTION

DOCK ENTRANCE AND POWER HOUSE

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DISCUSSION.

Mr. Shanley. Mr. Shanley asked whether any precautions had been taken to protect the timber against the teredo.

Mr. Ashcroft. Mr. Ashcroft answered that at that point the water was only slightly brackish, since there were one or two fresh water streams entering there. An old dock near which had been used for about twenty years, was in a very bad state of repair, but the decay was simply the rotting of the timbers, and not from the effect of the teredo. Farther down the Bay there would probably have been trouble experienced from the teredo.

Dr. W. B. Dawson. Dr. W. Bell Dawson added, by correspondence, that in comparing the capacity of dry docks, Mr. Ashcroft was very right in emphasizing the need for taking standard dimensions, which were comparable in all cases. Mr. Ashcroft had also considered that the depth of water over the entrance sill was the dimension next in importance to the length of the dock; but he was surely in error in adopting the minimum depth, or the available draft at low water, as the term of comparison. This might perhaps be allowable where the tide had a very small range, amounting only to two or three feet, as in the case of the dock at Baltimore, which he was describing, but where the tide had a greater range, it was the universal practice, both in Europe and on this continent, to admit vessels at high water, in order to take advantage of the additional draught then available. In some of the important Canadian harbors there was a tidal range of 18 to 24 feet, which it would be quite out of the question to overlook, or to lose the advantage of. It was also to be noted that where the rise of the tide was so great, it was not possible to open the dock gates except at high or low water, on account of the rapid change in the water level.

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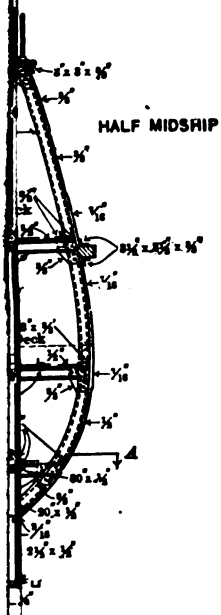
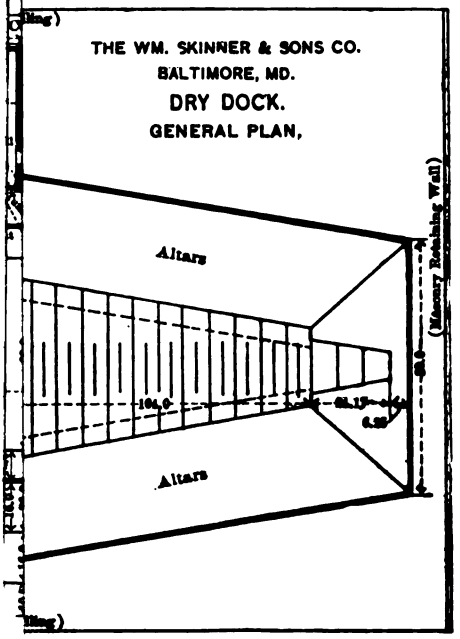


THE WM. SKINNER & SONS CO.
BALTIMORE, MD.

DRY DOCK.
GENERAL PLAN,



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PAPER No. 228.

THE BOUT DE L'ISLE BRIDGE.

By J. L. MORRIS, M. Can. Soc. C. E.

The Bout de l'Isle Bridge, though not forming one of the list of the International and Interprovincial bridges, as yet few in number, has claims to be classed with the prominent bridges of Canada.

It is composed of two crossings over the east and west branches of the Ottawa River, formed by Ile Bourdon, just above the junction with the St. Lawrence River at the foot of the Island of Montreal.

The location is practically the same as determined by the engineers of the Quebec, Montreal, Ottawa & Occidental Railway, as an alternative crossing of the Ottawa River for an entrance into Montreal for the through line from Quebec in 1874. This bridge now forms the crossing of the Ottawa River, for the Chateauguay and Northern Railway Company, on their line from the City of Montreal, to the Town of Joliette on the line of the Great Northern Railway, which now forms that part of the transcontinental line of the Mackenzie and Mann system which connects Quebec and Hawkesbury.

The west channel, that between the Island of Montreal and Ile Bourdon, is about 1500 feet in width, and the bridge crossing it comprises the following spans:—a deck plate girder 46 feet in length between the west abutment and pier No. 1; four through trusses each 140 feet in length from pier No. 1 to pier No. 5; a through truss 200 feet in length from pier No. 5 to pier No. 6; four through trusses each 140 feet in length from pier No. 6 to pier No. 10; and a deck plate girder 46 feet in length between pier No. 10 and the east abutment.

The distance across Ile Bourdon, between the abutments of the west and east channels is about 2100 feet.

The east channel, that between Ile Bourdon and Charlemagne is about 1300 feet in width, and is crossed by the following spans; a deck plate girder 70 feet in length between the west abutment and pier No. 1.

Seven through truss bridges each 140 feet in length from pier No. 1 to pier No. 8; a deck plate girder 70 feet in length between pier No. 8 and the East abutment.

The 2100 feet stretch across Ile Bourdon, is composed of earth embankment, while at the other end of both crossings, the approaches are built of temporary trestles, each about 2000 feet in length.

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The original contract for the sub-structure of the bridge was let to F. C. Dunn and Company of New York in 1902, who not being in a position to construct owing to the great hazards to be met with in the work, sub-let to the W. J. Poupore Company of Montreal in February 1903 all of the work coming under their contract with The Chateauguay and Northern Railway Company, being twenty five miles of railway line, which included the sub-structure of the Bout de l'Isle bridge.

Preliminary construction such as the cutting off of piles and the building of caissons was begun in the month of February, and continued until the 18th of March, when the breaking up of the ice compelled the Contractor to stop work until the Spring freshet had subsided, and the water had fallen in the St. Lawrence River. Much of this preliminary work was injured by the action of the ice, which was carried past the site in large blocks by the swift current.

Piles for the foundations of all piers and abutments were driven at about three feet centres, and this work was carried on during the winter of 1902-3 from the ice, which notwithstanding the strong current, formed to a good thickness, and made this part of the work an easy matter, especially as the material in the bed of the river caused no inconvenience in the driving of the piles, being of a stiff blue clay.

The Chateauguay and Northern Railway Company being responsible for the cutting off of the piles, as required for the foundations of the piers and abutments, made an effort to cut the piles of pier No. 4 by using one diver from an anchored scow. Owing to the swiftness of the current this was found to be impracticable, and the balance of this part of the work was carried out by the W. J. Poupore Company, who to ensure the safety of the men employed below water, took all the precautions which were possible. A large scow was securely snubbed to the heads of the piles, which came near to the surface of the water. Just above the piles upstream from the pier a temporary crib triangular in shape was sunk with the nosing upstream, which broke the current and caused practically still water around the piles. Even with this advantage it was considered inadvisable to use one diver in cutting the piles, and two were used in preference. As many as twenty four piles per day were cut off about 18 inches above the level of the bed of the river.

The foundations of the east and west abutments, and piers 1, 2, 3, 9, and 10 of the west channel, were constructed, together with all the foundations of the east channel by building cofferdams. Piers 4, 5, 6, 7, and 8 of the west channel had their foundations constructed by the use of caissons. These caissons were constructed 18 inches larger on all sides than the required dimensions of the concrete foundation of the pier, with 12″ x 12″ squared timber, well braced on the inside, then all joints well caulked so as to make it watertight.

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The timbers were scribed to fit the bottom of the stream at the site where the caisson was to be sunk.

At the placing of the caisson for pier 4, it was thought possible to anchor it in place by the use of three ship anchors, attached with cables to the nosing and corners of the caisson, but owing to the swiftness of the current and the slippery condition of the clay in the bottom of the stream it was found impossible to do so, and no effort was made afterwards to place any of the piers with them. It was at this pier No. 4, that owing to the anchors slipping, the caisson capsized and threw the men into the water. All the five caissons were finally placed by means of two cables attached to trees on an island about 2500 feet above the bridge site, and as a protection to the public were floated on cedar poles with spaces of about 30 feet between them, and attached one on each side of the caisson, and with a third cable against the current from the nearest pier on the work, we were able without mishap to place all of the caissons.

At the shore ends where the water was shallow and where cofferdams were used the concrete was brought to its finished level without delay, as there was no difficulty in keeping out the water from the cofferdams, but in those foundations where caissons were used, the concrete was filled under water to within five or six feet of the required level, and after five or six days the water was pumped out and the balance of the concrete brought to a finished level.

After the placing of the caisson and before any concrete was filled in, the diver made a careful examination of the bed of the river within it, and of its bearing on the bottom. The only difficulty was with pier 5, which did not fit the irregular bottom, and it was necessary to line the inside of the pier with heavy canvas, and place concrete in bags around the inside edge of the caisson to stop the flow of the water through the concrete, and prevent the carrying away of the cement and sand.

The concrete used in the foundations was composed of 1 part of cement, 2 parts of sand, and 5 parts of broken stone. The brands of cement principally used were Invisible (a Canadian cement) Dyckerhoff, and Haemoor (both German cements).

The supply of crushed stone was brought from the quarries of the W. J. Poupore Co., at the east end of Montreal, and delivered to the work on large scows.

The level of the finished concrete in the foundations was 1 foot below the low water level for piers 2, 3, 4, 5, 6, 7, 8, and 9 of the west channel, and for all piers in the east channel. The abutments of both crossings were 44 feet in width, 22 feet and 6 inches from the top of the concrete to the bridge seat, and 5 feet from the bridge seat to the top of ballast wall. The thickness of the abutment at the

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bridge seat was 6 feet, the front wall having a batter of 1 in 24. Piers 1 and 10 in the west channel were 27 feet and 6 inches in height above the concrete, with a width of 6 feet at the top, and a batter of 1 in 24 on all sides, the bridge seats for the longer spans being lower than for the shorter spans bearing on these piers. The upstream end of all piers have cutwaters commencing at the level of the concrete foundation and reaching to within about four feet of the level of the bridge seat. The lower or down stream ends of the piers are circular, and so carried up to the bridge seat level.

Piers 2, 3, 4, 5, 6, 7, 8, and 9 of the west channel are similarly constructed, all being 30 feet in height above the concrete foundation to the bridge seat level, 6 feet in thickness at the bridge seat, and with a batter of 1 in 24. The piers 1 to 8 inclusive of the East Channel crossing are all 25 feet in height above the concrete level to the bridge seat, 6 feet in width at the bridge seat, and with a batter of 1 in 24. These piers were otherwise built similarly to those of the West Channel.

All stone supplied for the masonry of this bridge came from the Terrebonne quarries in courses ranging from 18 to 30 inches in thickness, and is a good quality of limestone for pier construction. The mortar used in the work was composed of one part of cement and two parts of sand.

Much expense was incurred in the handling of the stone, which was first unloaded from the cars at the west end of the west crossing, and distributed from this point by lorry cars to temporary wharves, and then loaded on scows and towed to the pier where required. This necessitated, especially during the low water season, temporary wharves at both shores of the two crossings, and as the water receded these had to be further carried out so as to give sufficient of water to float scows and tugs.

At the latter part of the season the water in the east channel became very shallow, and the larger scows could not be brought to the site of the bridge, when loaded with building material. A landing place was made about 1000 feet below the crossing and the material transferred to smaller scows, and towed to the work with tugs of very light draught. This necessarily caused considerable delay in carrying on the work. The Engineers of the Chateauguay and Northern Railway laid out all work without using triangulation, for the placing of caissons and the centering of piers. This was made practicable, by having good ice to work upon during the winter, and making use of the piling of the foundation of the piers, which in all cases came near to the surface of the water, and allowed of the Engineers making steel tape measurements from pier to pier. The measurements given by the Engineers worked out satisfactorily, both as to centre and span.

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The first masonry of the west channel was laid on April 1st 1903, and on September 10th of the same year the substructure was complete comprising 2 abutments and 10 piers, which contained 2138 cubic yards of concrete in foundations, and 2983 cubic yards of masonry. The steel work was completed over this channel about the 1st day of October.

The masonry of the east channel was commenced on August the 10th 1903, and completed on November the 15th 1903, comprising 2 abutments and 8 piers which contain 600 cubic yards of concrete in foundations, and 2060 cubic yards of masonry.

On the 25 miles of Railway construction between Bout de l'Isle and Joliette four smaller bridges and seven arch culverts were built at the same time as the Bout de l'Isle, and contained 3500 cubic yards of concrete.

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BUSINESS MEETING.

A business meeting of the Society for the opening of ballots for the election of members was held on Thursday, May 11th, 1905, Mr. Phelps Johnson in the chair. Messrs. J. W. Heckman, J. A. Jamieson, C. H. McLeod and G. Legrand having been appointed scrutineers, declared the following elected:—

HONORARY MEMBER.

THE RIGHT HONORABLE EARL GREY, G. C. M. G.

MEMBERS.

F. F. BUSTEED.
J. P. FORDE.

ASSOCIATE MEMBERS.

M. B. ALMON.
J. E. BEATTY.
R. M. CHARLTON.
ST. G. J. HARVEY.
J. V. NIMMO.
E. H. PIERCE.
CRAVEN GARNETT.

TRANSFERRED FROM CLASS OF ASSOCIATE MEMBER TO CLASS OF MEMBER.

E. A. HEBERT.
J. O. A. LAFOREST.
H. R. LORDLY.
C. N. MONSARRAT.
P. B. MOTLEY.
D. WEATHERBE.

TRANSFERRED FROM CLASS OF STUDENT TO CLASS OF ASSOCIATE MEMBER.

A. S. COOK.
W. A. DUFF.
J. T. FARMER.
H. J. A. HAFFNER.
H. P. RUST.

STUDENTS.

C. D. G. BOOTH.
A. V. CHASE.
W. R. DEVENISH.
S. A. DESMEULES.
G. W. F. EVANS.
E. O. FUCE.
E. S. HOLLOWAY.
S. S. MCDIARMID.
A. K. MACCARTHY.
W. W. MCGREGOR.
G. G. MURDOCH.
E. N. RIDLEY.
N. D. WILSON.
F. S. WINSER.
L. E. H. LIPPE.

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PAPER No. 229.

AN INVESTIGATION OF A 16 K. W. CONSTANT CURRENT TRANSFORMER.

By C. H. WRIGHT, S. Can. Soc. C. E.

INTRODUCTORY.

The principle of a constant current transformer was first described in a paper presented before the American Institute of Electrical Engineers by Professor Elihu Thomson, on May 18th, 1887, and published in the "Proceedings" of that body in the London "Electrician." Following this there appeared in the London "Electrical Review" of April 16th, 1887, an article by Professor Thomson, describing the effects of replusion between primary and secondary, and entitled "New methods of regulating current and potential in secondary of transformers." On January 10th, 1889, an application was filed for a patent on constant current transformers which regulated by means of a variable magnetic leakage, the opportunity for leakage being intentionally made very great by winding the primary and secondary on the separate legs of an iron core, and so shaping the core that a great many of the lines generated by the primary could divert themselves from interlinking the secondary. An application was filed June 8th, 1891, for a patent on a constant current transformer which regulated by the variable leakage produced by a moveable secondary, and later for one with both primary and secondary moving differentially, the principle being essentially that of the present type.

DESCRIPTION AND METHOD OF OPERATION.

The component parts of the 16 K. W. or 25 light constant current transformer tested are:—

(1) A laminated iron core of the double magnetic circuit type, but of an exaggerated height, and of a ш shape, the top cross pieces being driven in after the coils were in place. The whole core is mechanically strengthened by iron castings at top and bottom, connected by wrought iron stay bolts and buck staves.

(2) A primary coil of 282 turns, rectangular in plan, and firmly fastened in the bottom of the spaces within the iron circuit.

(3) A secondary coil of 615 turns, rectangular in plan and fitted at each end with a brass casting, by which the coil may be moved bodily up and down the central part of the iron core.

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(4) A lever pivoted on two knife-edges; furnished on one end with circular arcs, from which the secondary is suspended by a chain, and on the other end with an involute whose eccentricity may be adjusted. From the involute is suspended a set of adjustable weights, whose function is to nearly balance the weight of the suspended secondary.

(5) A tank of convoluted cast iron, or boiler iron, and cover. This tank is nearly filled with a special oil, which serves not only as an insulator, but also as a mechanical damper and heat radiator to the movements of the secondary.

The following data were taken from the name plate:—

No. 257149.

Specification No. 12216.

Type R.

Form A E'.

Cycles $= \frac{60}{125}$

Kilowatts 18.

Primary volts 1100.

Secondary Amps. 6.6.

This transformer is designed to operate series loads, and consequently must furnish a constant current with a voltage so varying as to maintain this current irrespective of the load in the external circuit. The primary is run from constant potential mains, and so the method of variable leakage is used to effect regulation.

With the coils in any given position the transformer acts as a simple static transformer, but with such a great amount of magnetic leakage that the ratio of the voltages called for by the ratio of turns is not attained. With the coils close together, i.e., in full load position, the flux generated by the primary is nearly all embraced by the secondary, hence we have the maximum voltage corresponding to 80 volts apiece for about 27 lamps. Now suppose the external load to be decreased by cutting out five lamps say; if this voltage did not change, the current would obviously become greater than the normal value of 6.6 amperes, and the repulsion action between primary and secondary would increase. As the coil is so nearly balanced by the counter-weights, it is practically floating in the air, so this increased repulsion causes the secondary to rise, thereby making a considerable area between the coils across which leakage takes place. This leakage reacts on the primary alone, the primary inductance is thereby increased and the current lags farther behind the E. M. F. We now have the condition of the secondary embracing fewer lines of force and consequently generating a lower E. M. F., and by properly adjusting the weights the E. M. F. can be made to be such as to maintain the current at its normal value of 6.6 amperes. As the force of repulsion does

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not vary in direct proportion to equal increments of secondary current, the involute is added to compensate for these variations.

In the extreme case, if the secondary be short circuited, the coils assume the no load position with the secondary at the top, and consequently the leakage is a maximum. On the other hand, should the external load be increased and the current be momentarily lowered, the repulsion would be lessened, and the secondary would move downward to a position where it embraced more l nes, causing the voltage to rise.

It was mentioned above that the primary inductance increased in proportion to the amount of leakage. This brings out rather a remarkable result, for in the regulation test the primary current is seen to be practically the same for all loads, whereas the actual power supplied varies very closely with the load. The operation then is a result of a varying primary power factor, or a variation of the energy component of the current and the movement of the secondary into positions involving different leakage factors, but this does not involve a waste of energy in the primary except for losses.

Practically, the operation of the transformer depends upon the utilization of the variations in repulsion, between the primary and secondary as a mechanical means of producing a variation in the leakage factor. It was desired to analyze the workings of a transformer when regulating, and when blocked so as to prevent regulation. The data obtained are from runs made on lamps, pure non-inductive loads, and purely inductive loads. The different constants show the effects and defects of the regulation, and in many of these tests qualitative results were looked for rather than quantitative, as precision could not be expected with the low power factors reached in some of the runs.

Method of Making Tests.

Both primary and secondary were furnished with ammeter, voltmeter and wattmeter, the voltage of the second being reduced by potential transformers of variable ratios. The power was derived from the 10-pole motor driven generator run at 60 cycles in the shop, and also from one run compound. The first non-inductive run taken was with the compound machine. A set of different readings were taken from nine different blocked positions of the secondary, at current values varying from 10 to 1. From the values of each of these positions the apparent watts and power factors were also calculated, and plots were made according to 1, 3, 5, 9.

Inductive Load.

The first method employed as a means of obtaining a variable inductance, was to run the output into the primary or secondary

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coils of a 50 light constant current transformer, and then by short circuiting the remaining coils and varying their position to so vary the inductance as to obtain desired readings on the instruments precisely as in the non-inductive runs.

The next arrangement tried was that of a large transformer coil so arranged as to be moveable on a ⊔ shaped core, and thus capable of being associated with a variable iron circuit. This did not have a great enough range owing to the high voltages sometimes used. From the values observed, and apparent watts and power factors calculated, sheets 2, 4, 6 and 9 were made.

Core Loss and Exciting Current.

This test was taken on the primary with the secondary open. Readings were taken of the voltage, amps., and watts under these conditions, the instruments being so arranged that the drop in the ammeter and series coil of wattmeter shall be included by pressure coils in voltmeter and wattmeter.

The exciting current was about 6.6 amps.

VOLTS		WATTS		
Observed. —	Corr.	Observed. —	Corr.	
110	110.4	48.4	439	Core loss corrected
110	110.4	48.5	49.0	for voltage
110	110.4	48.5	49.0	= 468 watts.
110	110.4	48.6	49.1	
	110.4		49.0	

The primary volts were thus too high when the calibration error was taken into account. As the difference is very slight, we may assume a straight line variation of the loss with the voltage. Applying correction to the loss as read we get

$$\frac{\text{true loss}}{\text{observed loss}} = \frac{110}{110.4} = \frac{W}{490}$$

$$\therefore W = \frac{110 \cdot 490}{110.4} = 488, \text{ which is the true core loss in watts.}$$

The copper loss in primary, due to this small exciting current, would be roughly

$$\text{W. Cu.} = (.66)^2 \ (.1102) = C^2 \ R.$$
$$= .048 \text{ watts.}$$

This is entirely negligible in the value 488, which is good for about ½ of 1%.

From value of exciting current and core loss we can calculate the magnetizing current, for since the current to overcome hysteresis is in phase with the electromotive force, its value is

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equal to the watts read divided by the E. M. F. read. This gives the value of the component in phase.

$$C = \frac{388}{1100} = .44 \text{ amps.}$$

Now the magnetization of the exciting current is in quadrature with the E. M. F., and as we have the mean square value of this exciting current for the ammeter

$$C = c - j\,c^2$$
$$.66 = .444 - j\,c^2$$
$$\therefore c^2 = .434 \text{ amps. magnetizing current.}$$

Core Loss Variation.

It seems very probable that there is a variation in the core loss from one position of the coils to another with the accompanying variations of leakage. As measured, the core loss is that due to a certain definite flux traversing the iron, and this is practically the whole flux generated, and as the current is drawn from the secondary some of this flux is diverted and, provided the coils are any distance apart, leaks across the air spaces of the yoke, so that the iron above the secondary coils is thus carrying less flux than it was when the core loss was measured.

All the iron, then, above the secondary, including the upper cross-piece of the yoke, is worked at lower density, and consequently the area of the hysteresis loop being less, the energy consumed must be less. This difference must grow less as the coils approach the full load position, as then the opportunities for leakage would be reduced, and more of the flux would have to pass through the secondary and through the upper portion of the iron circuit. At full load position the opportunity for leakage must be very small, so that the greater part of the flux would actually traverse the iron circuit, as at open circuit, but here the demagnetizing effect of the secondary is so disposed as to be in its most favorable position.

It would seem that the upper portion of the yoke was at all times merely carrying a differential flux, and that this difference was by no means constant. There appears to be no means of measuring this variation except by a determination of the total losses of the transformer by some method such as the ice calorimeter, and then subtracting the C^2R losses of primary and secondary secondary.

Heat Run.

The heat test was run at normal voltage, frequency and current, with two inch space between stationary and movable coil.

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PRIMARY.

Hour A.M.	Temp. air.	Temp. oil.	Volts.	Amps.	Rcs.	% rise.	Rise in degrees.
8	18.3	18	110.0	14.9	.655	8.4	21.85
9	19.	23	110.0	14.8	.721	11.6	21.85
10	18.	27	110.0	14.8	.742	12.0	31.20
11	18.	30	110.0	14.7	.745	13.4	34.75
12	18.5	32	110.0	14.8	.754		

SECONDARY.

2060	6.6	3.655		
2080	6.6	3.975	8.8	22.8
2080	6.6	4.104	12.3	31.95
2060	6.6	4.167	14.0	36.40
2080	6.6	4.181	14.4	37.45

Remarks:—

Oil in tanks one-half hour before run.

Initial resistance taken without oil in tank.

The resistance is calculated from $C = \frac{E}{R}$

The temperature rise was calculated from the formula

$$T_r = (238 + t_1)\left[\frac{R_2}{R_1} - 1\right]$$

where T_r = temperature rise in C.

t_1 = average temperature of room during test.

R_1 = resistance hot.

R_2 = resistance cold.

The degrees rise were calculated from the % rise in resistance by the formula

Degree rise = K × % rise in degrees.

where $K = (1 + 25 + T)\ (2.5)$

$= (1 + .04)\ (2.5) = 2.60.$

IMPEDANCE.

The impedance is measured by observing the voltage and current on the primary when the secondary is short circuited. The primary voltage is, of course, lowered to such a degree as to give the normal current of 6.6 amperes as read by the secondary ammeter. The impedance was measured by the two extreme positions of the secondary.

	Sec. current.	Prim. Volts.	Prim. current.	Impedance.
Coils apart	6.6	964	14.7	65.5
" together	6.6	153	14.49	10.5

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The fact of having lowered the E. M. F. does not in any way affect the value of the impedance, as the inductance and periodicity are the only factors which enter into the component, and these, like the resistances, are constant specific properties of the primary at any given position of the secondary;—the latter, of course, carrying its normal current.

Reactance.

From the impedance and the value of the primary resistance, the reactance at the two points may be calculated.

$$Z_1 = r_1 - j\,x_1$$

$$65.5 = .1102 + j\,x_1$$

$$x_1 = \sqrt{(65.5)^2 - (.1102)^2}$$

$$= 65.5 \text{ ohms.}$$

This shows that even at full load the primary resistance is literally swamped by the reluctance, and that the impedance and reactance are practically synonomous.

Inductance.

The absolute inductance in henries may be calculated from the reactance and the frequency.

$$x_1 = 2\,n\,l_1$$

$$l_1 = \frac{x_1}{2} = \frac{65.5}{2 \times 3.142} = .141 \text{ henries.}$$

$$l_2 = \frac{x_2}{2n} = \frac{10.5}{2+3.142} = .0167 \text{ henries.}$$

A table of these constants of the primary is given below:—

Position of coils.	Periodicity.	Resist. in ohms.	Impedance.	Reactance in ohms.	Inductance in henries.
apart	60	.1102	65.5	65.5	.142
closed	60	.1102	10.5	10.5	.0167

Discussion of Results.

The tests made on lamp loads are the ordinary regulation tests, and readings were taken at each position, so that it was possible to plot curves on sheet 7.

The lamps used are known as the Form 3 series alternating current Thomson enclosed arc. They are of the differential type, the series and shunt magnets each consisting of two solenoids

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placed side by side. The armatures are U shaped and laminated, and are attached to opposite ends of a lever which actuates the carbon feed clutch. Adjustment for proper arc voltage, in this case 80 volts, is by means of a sliding weight on this lever. The ampere curve is seen to be very nearly a straight line within the limits of regulation, and the drop on 20% overload is but 0.1 amps. The way in which this curve follows the voltage load is very clearly shown, and the watt curve shows very plainly the almost linear increase of energy supplied. The drop in voltage, and consequently in current is not, however, due to decreased efficiency at overload, as is shown by the change in direction of the watt curve when the current starts to fall off, and also by the flat efficiency curve. The secondary power factor appears to be highest at about ½ load, but does not drop below 85 even at 20% overload. The left hand dotted ordinate is drawn at 25 lamps, and the right hand at 27 lamps, the latter being considered equivalent to a 10% line loss. This performance shows the transformer is able to regulate over very wide ranges of load without a great change in efficiency, and although the primary factor may drop as low as 50% on 3/5ths. load, it is about 77 or 78% on full load, with even higher factors on overload. Considering that the power factor introduced by the lamps in the secondary circuit is 84, the internal reactive effect of the transformer is seen to be reasonably small, and the consequent excess of copper losses introduced in transformer, line and generator is inappreciable.

Non-Inductive Load.

The result of the runs on non-inductive load show better than any other what we may call the "intrinsic properties" of the transformer; primarily, because the variations of current are very nearly proportional to the variations of actual energy involved; in the second place, because the generator compounds more accurately on such loads, and gives more approximately sine waves; and thirdly, because of the greater precision of the measuring instruments when used on higher power factors. An inspection of Sheet 1 shows how, with the coil blocked, an increase in the demand for current causes a decrease in the secondary voltage due to the increased magnetic leakage thereby resulting. This is shown most strikingly in the two lower curves, where the opportunity for leakage was great, the voltage falling to zero before the current could reach a great enough value to blow the fuse.

This effect becomes less and less pronounced as the coils are blocked nearer and nearer together, the path for leakage becoming less and less, and the transformer approaching more the static transformer type. All the curves up to the third or fourth from

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the top show a fall in voltage more than proportional to the increase in current and appearing convex upward; but above these two curves there is a pronounced tendency to a convex downward curve, the voltage not falling off proportionately to the increased current. The only probable explanation of this seems to lie in the fact that the space across which the magnetic leakage must take place is more constricted, and although leakage can and does take place, the area of the inside portions of the core legs from which the leakage must emerge is so small as to cause the iron at these points to approach saturation and force a proportionally greater number of the lines to link the secondary than would otherwise do so. If the area was infinitely small, no leakage could take place, and we would then have a pure static transformer, with constant secondary potential minus copper losses. The fourth curve from the top in Sheet 1 may be taken as the limiting case where the leakage is proportional to the increase in current and the plot is a straight line. This plot shows clearly how the transformer would act if the coils were not blocked. Suppose, for example, the current to be 6.6 amps. on a very light load, corresponding to a definite voltage on the lowest curve (about 800 volts); now an increase of load would momentarily cause the current to drop, and the coils would swing to a new point as represented on the curve above (about 1300 volts). Successive increments of load would cause the 6.6 amperes to travel from curve to curve until it finally reached the highest curve at a certain overload, beyond which point the transformer would no longer act as a constant current transformer, but increased load would mean decreased current, with but very slight increase of voltage up to the infinite load point of about 2100 volts. The watt curves on Sheet 3 are very interesting, and show a decided resemblance to the current curves in many respects. The four lower curves intersect at zero at the two points where the current and voltage, respectively, are equal to zero and, of course, all the other watt curves would do the same if the transformer had been able to carry the current required to pass through their complete cycles. These curves show a marked symmetry and, moreover, they all appear to have a maximum value of about 1400 volts, and to be symmetrical about the axis of 1400 volts. This could not be explained, but undoubtedly the proper equational relation, if differentiated, would show some such maxima, and it seems probable that this would be at 1200 volts instead of at 1400. It is also probable that the symmetry would disappear on the upper curves, due to the same cause as the upper bending of the current curve of Sheet 1. The two plots of Sheet 5 show very clearly the variation in power supplied, and in the power factor with the primary current. Both plots exhibit the general tendency in all the plots of the dropping away of energy

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as the current tends to rise in the secondary circuit. The lower plot shows very graphically the actual power supplied at the different positions of the secondary coil, and, together with the upper plot, the fact that low secondary loads mean automatic throttling of the power supplied to the primary, due to the introduction of a lower power factor. The upper curves of the lower plot are almost exactly such as would be obtained from a static transformer, and the upper curve of the power factor curves is the "dip," which occurs in all of them between the values of four and ten amperes. This appears in every one of the nine curves at about the same point, which, of course, involves readings at widely different points on the instrument scales.

Inductive Load.

The runs on inductive load were intended to show the action of the transformer in different positions, when subjected to the most severe conditions as regards lagging current and the entirely disproportionate heating involved. The load was very nearly purely inductive, as was described previously, and consequently the decision of some of the readings, particularly the wattmeter, was somewhat low, the results being shown in Sheets 2, 4, 5 and 9.

The curves in Sheet 2 showed a marked difference from the secondary obtained non-inductive curves in Sheet 1, the falling off of voltage on increase of current being very nearly linear, in every case, the slope of the line being greater in the lower load positions than in the higher and full load positions. This indicates very clearly that the regulation on inductive loads would have to depend entirely on the movement of the coils, and that inductance should be avoided on lamps on any load which it was desired to operate, especially on full load or overload.

For the sake of comparison, an extra load run on non-inductive load was taken at the full load position and plotted (the uppermost curve in Sheet 2). The difference between the non-inductive curve and the inductive load curve is most marked, the former being very much more stable.

The watt curve in Sheet 4 all exhibit a greater steepness than the corresponding non-inductive curve of Sheet 2, the effect being more pronounced than in the current curves, as might have been expected. They do not exhibit the same symmetry, and do not bend round towards the axis of zero watts as those of Sheet 2. This may be explained by the fact that the "ohmic resistance" of the external load being constant, the energy expended in it is directly proportional to but one variable—the square of the current. —consequently, although the terminal voltage of the transformer may be much less, due to a greater load produced by a decrease in

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the external inductance load, the resultant increase of current causes a greater expenditure of energy in the form of C^2R. The apparent irregularity of the upper curves may be due in part to the actually small, but proportionally large, increase of resistance of the coils of the variable inductance due to their excessive heating.

The two curves of Sheet 6, when compared with the corresponding ones of Sheet 5, show the same general difference as did the current and watt curves. On account of the low precision of the results, and the nearness together of the separate curves, the two extreme positions only were plotted, the intermediate curves being either indicated or omitted. The upper set of curves shows the extremely low power factors obtained, and the curious way in which they varied as compared with those of Sheet 5. The lower set shows how the energy input of the transformer increased with increase of current; almost the reverse of the case on Sheet 5,—the reason, of course, being that mentioned in the case of the watt curves, namely, that the C_2R load increased as the total of inductance load decreased and the lag became less.

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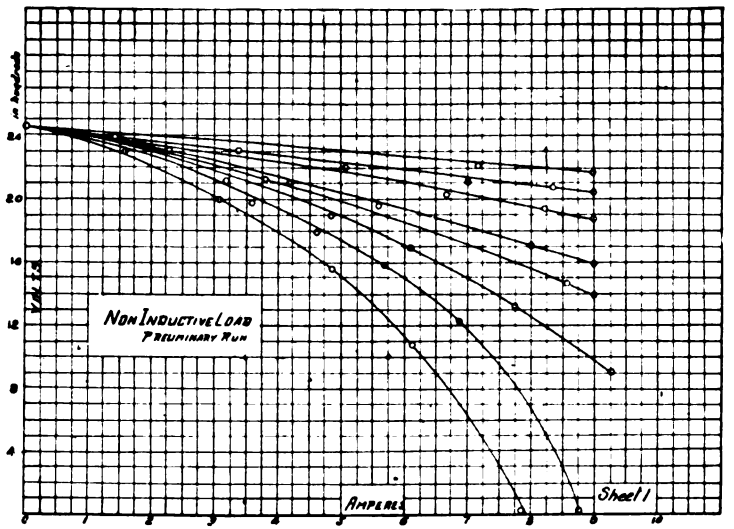

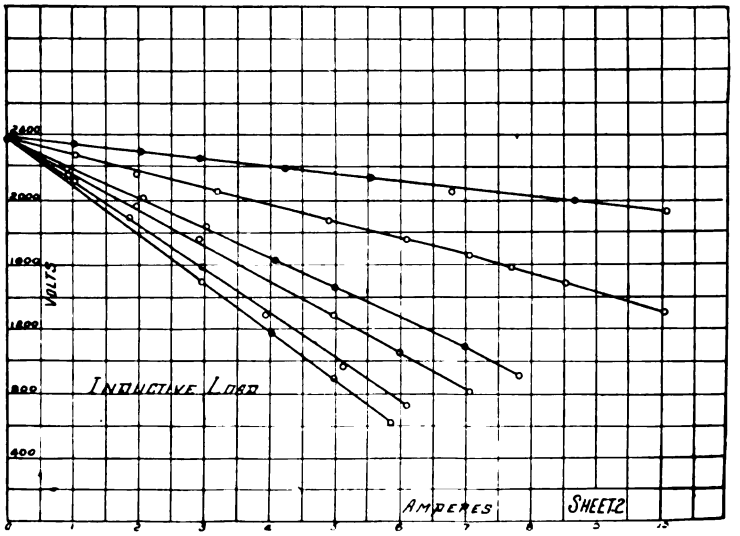

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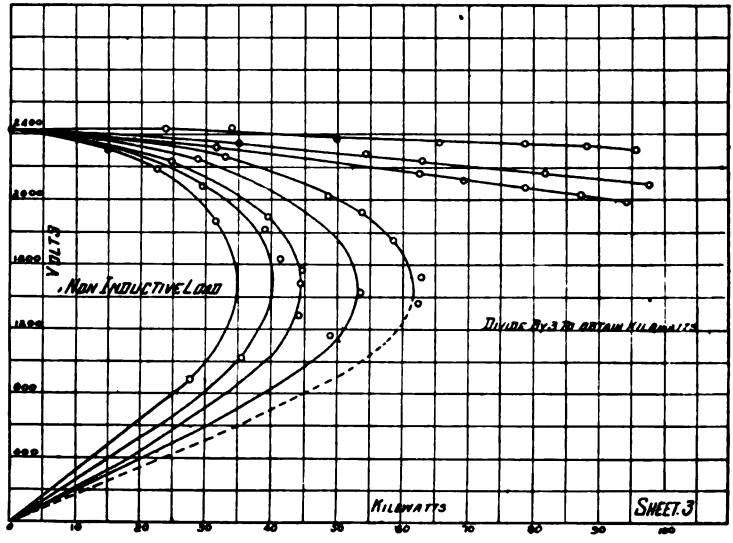

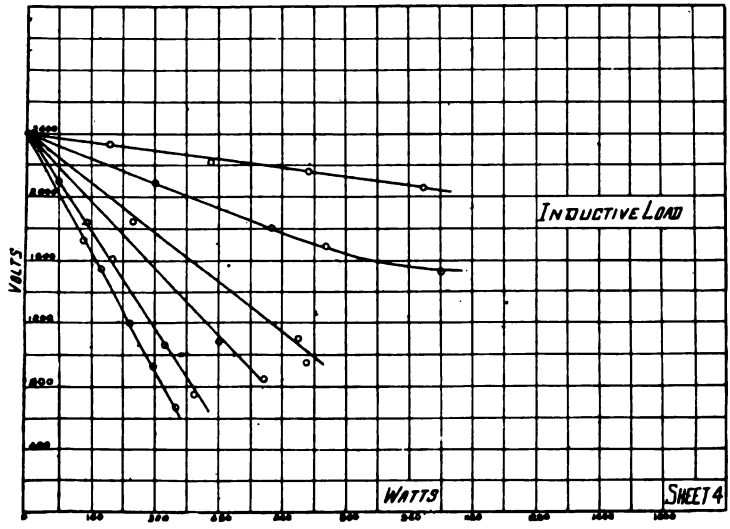

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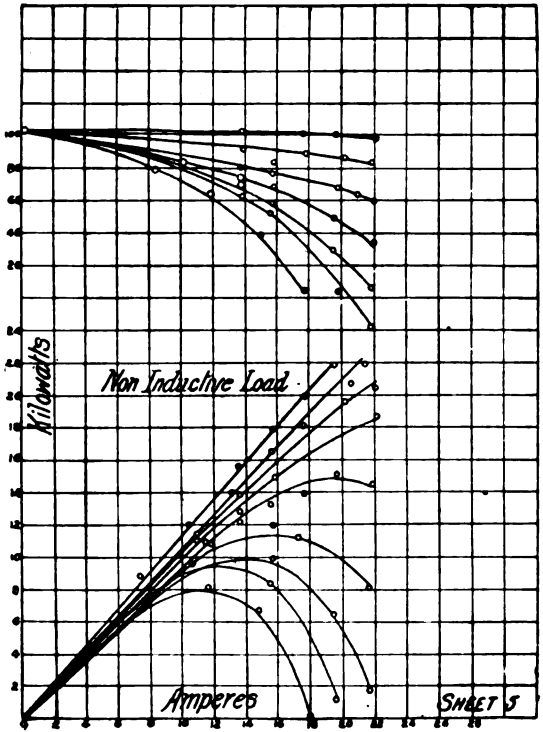

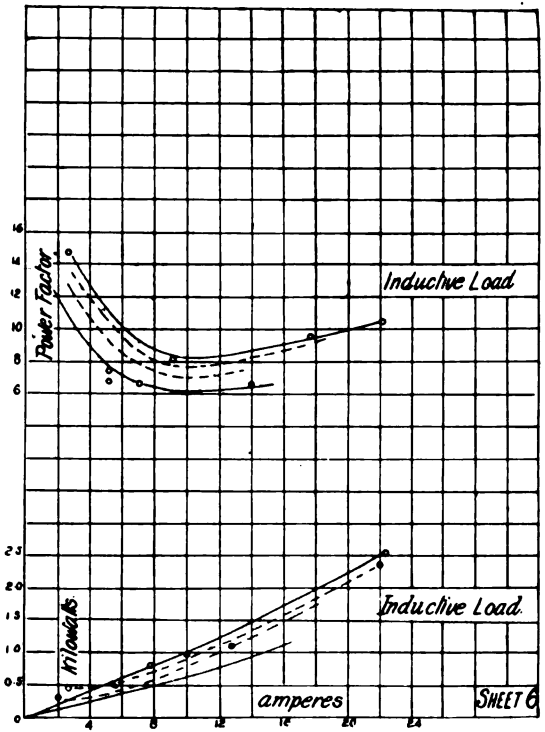

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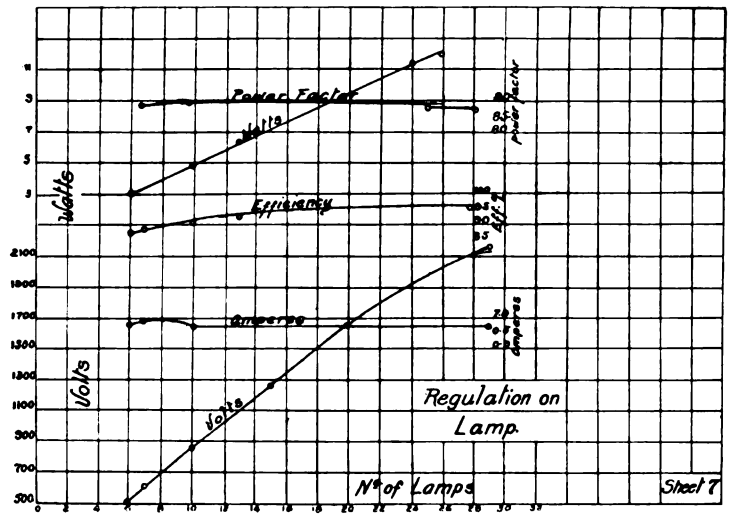

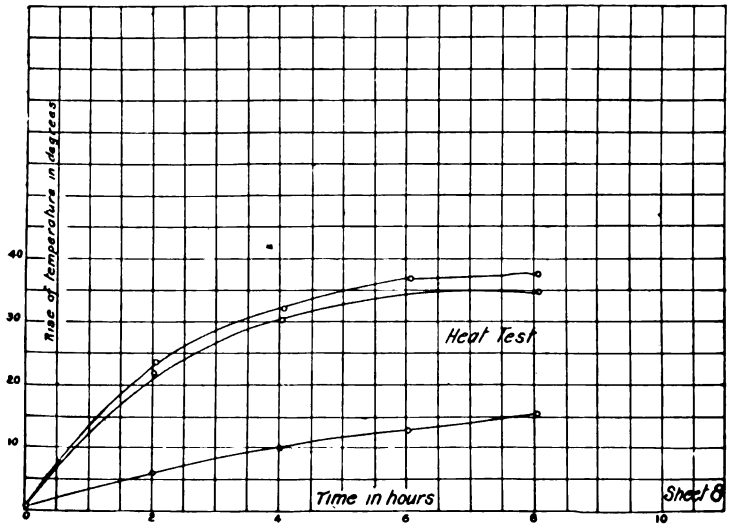

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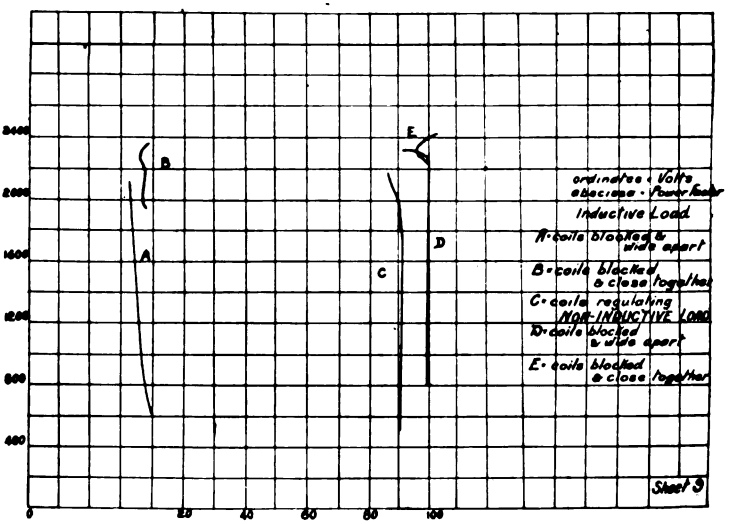

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BUSINESS MEETING.

The session was opened by a business meeting, held on Thursday, October 12th, for the opening of ballots for the election of members, Mr. J. A. Jamieson in the chair. Messrs. Jamieson, McNab, Heckman, Legrand, and Jost having been appointed scrutineers, declared the following elected:

MEMBERS.

F. A. Bowman.
J. J. Collins.
G. W. Catt.
W. Cross.
A. C. Joly de Lotbinière.
C. E. Perry.
T. K. Thomson.

ASSOCIATE MEMBERS.

F. W. Angel.
T. A. Bown.
F. S. B. Calcott.
J. G. W. Campbell.
F. E. Courtice.
W. F. Jennison.
A. LaRocque.
W. H. Magwood.
D. Morrison.
R. S. Dahl.
J. E. A. Egleson.
A. S. Fairbanks.
H. E. Heustis.
M. G. Henniger.
C. Reaves.
C. P. Sanders.
A. T. Spencer.
W. W. Van Every.

Transferred from the class of Associate Member to the class of Member:

F. A. Creighton.
H. J. Lamb.
G. A. McCarthy.

Transferred from the class of Student to the class of Associate Member:

E. F. T. Handy.
S. B. McConnell.
J. O. O'Sullivan.
W. P. Wilgar.

ASSOCIATES.

T. Simmons.
E. Van Winkle.

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STUDENTS.

A. Babin.
A. H. W. Birch.
J. Bonin.
C. J. Bruce.
M. M. Campbell.
H. B. Cressman.
A. R. Crookshank.
S. Dingwall.
A. Dick.
A. Ferguson.
L. R. Gransaull.
J. H. Grice.
H. M. Haughton.
F. H. Kitto.
H. F. McDonald.
J. A. C. MacDougall.
C. C. Malloch.
J. R. Morrison.
J. P. Menard.
R. H. Mulock.
P. J. B. O'Sullivan.
A. A. Paradis.
S. J. Tuck.
J. de Stein.

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ELECTRICAL SECTION.

President—R. B. OWENS.
Vice-President—M. J. BUTLER.

A meeting of the Electrical Section was held Thursday, November 2nd, 1905, Dr. R. B. Owens in the chair. The following papers were read:

PAPER No. 230.

AN ELECTRIC ACCELEROMETER.

By R. B. OWENS, M. Can. Soc. C. E.

The advent of the electric motor as a competitor of the steam engine, especially in the traction field, has given rise to certain acceleration problems unfamiliar to engineers of a generation ago. At a time when the train mile was a satisfactory unit in which to reckon haulage costs, there was little occasion to bother with acceleration. Now, however, when neither the train mile, car mile, nor ton mile suffice, even when coupled with a speed factor as a basis of estimation and analysis, now when to maintain certain schedules more energy is expended in accelerating than in overcoming frictional and grade resistances, a simple, accurate, and reliable means of measuring acceleration is urgently demanded,—a means at least comparable in simplicity and accuracy with those employed in the measuring of the quantities of which it is the second and first differential with respect to time. The measurement of length is familiar to all. Of practical methods of measuring velocity or speed, at least of machines, one of the most satisfactory, if not the most satisfactory, involves the use of a suitable constantly excited or permanent magnet dynamo mechanically driven by the piece whose velocity is to be measured, and electrically connected through an ammeter to a circuit of constant co-efficients as shown in Fig. 1.

S is the shaft whose velocity is to be measured. C is a mechanical coupler. A is the armature of a small permanent magnet or constantly excited continuous current dynamo wound so as to have a negligible reaction within the limits of its use. R is a variable non-inductive resistance and I is a zero centre d. c. ammeter. The reading of I will be proportional to the speed of S and by adjusting R, can be calibrated in the revolutions per minute, feet per second, or miles per hour as desired. As the current through

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I is proportional to speed, it is only necessary to determine the rate at which the current varies in order to have a measure of acceleration. This is simply and easily done by inserting in the circuit with I a transformer T with its secondary connected, for purposes of adjustment, through a non-inductive resistance R_1, to a zero centre d. c. voltmeter V (see fig. 2). The reading of the voltmeter V will then be proportional to the acceleration, positive or negative, of the shaft S.

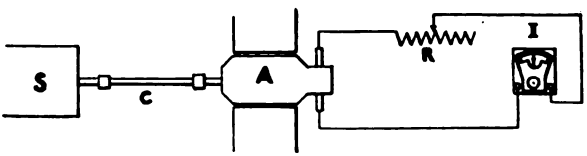

FIG. 1.

Substituting recording instruments for the indicating ones shown, we have a recording speed indicator and a recording accelerometer. The transformer must have a straight line saturation curve and a large transformation ratio as the secondary induced voltage is necessarily small and the voltmeter V must also be sensitive. The calibration of the ammeter as a speed indicator is effected by driving the armature A at different constant speeds as shown by ammeter reading, and taking the revolutions in a given time by means of a revolution counter and stop watch. The calibration of the voltmeter as an accelerometer is best done by driving the armature A by a separately and constantly excited motor having applied to its armature, preferably of small momentum, a voltage varying approximately as a linear function of time. With proper manipulation of apparatus the ammeter readings plotted against time will be a straight line whose slope will be constant and equal to the acceleration and to the constant reading of the voltmeter to within a constant.

In some tests made in the writer's laboratory not long ago, A (see again fig. 2) was the armature of a small low voltage separately excited d. c. generator; S the shaft of a 3 h.p., separately excited

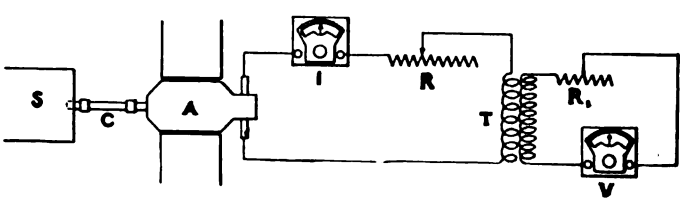

FIG. 2. .

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d. c. motor to whose armature by a potentiometer arrangement a steadily increasing or decreasing voltage could be applied; I and V Weston ammeter and millivoltmeter and T a small lighting transformer with a transformation ratio of 20. Excellent results were obtained, speed and acceleration being read to exactly the same degree of accuracy that Weston d. c. ammeters and voltmeters are capable of. With recording instruments substituted, this would seem to meet every requirement of a practical apparatus for the measurement and recording of velocity and acceleration in railway work, both steam and electric, and is applicable, of course, in many other connections.

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PAPER No. 231.

OSCILLOGRAPHIC RESEARCHES ON SURGING IN HIGH TENSION LINES. BY C. DAVID.

Abstracted with Introduction by L. A. HERDT, A.M. Can. Soc. C.E.

When a current is flowing through a circuit containing inductance, energy is stored in its magnetic field, the amount of energy being equal to one-half the product of the inductance into the square of the current. If the E.M.F. producing the current be suddenly removed, this energy will dissipate in heat. If the circuit be suddenly opened, the rate of the dissipation of the stored energy will be great and consequently the E.M.F. will be very high. In addition to magnetic reactance, a circuit will have more or less electrostatic capacity, that is, a certain quantity of electricity is required to charge the line. This energy is stored and will be restored again when the line is discharged. The amount of energy stored is one-half the product of the electrostatic capacity of the line into the square of the voltage. Energy is therefore stored in two ways in a system of electrical conductors.

A change of circuit condition taking place, as the switching on or off of an additional line, the opening of a circuit with or without load, sudden changes of load, etc., may cause violent and sudden alterations in the energy condition of the circuit, setting up electric oscillations which are liable to give rise to destructive voltages extending over the whole system and causing breakdowns of insulation.

When a transmission line is switched on busbars maintained at constant potential, the line may be considered as a condenser with inductance and resistance in series. According to theory (Steinmetz—Transactions of A.I.E.E., 1901, Oscillations in High Potential Transmission Lines), the maximum value of the oscillating E.M.F. induced is equal to the impressed E.M.F. producing the surging; that is, when a line is connected to a source of E.M.F. the potential may rise to double potential and will then oscillate between this value and zero with continually diminishing amplitude. The amplitude of the oscillations set up depends on the point of the impressed E. M. F. wave at which the circuit switch is closed. Also the frequency of the oscillations set up is independent of the impressed frequency but depends on the line constant.

Theoretically, then, the maximum rise of potential which can occur in connecting a transmission line to the generator busbars when the reflected surge adds to the impressed E.M.F. is 100%.

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In practice it will be seldom that the switching takes place when the impressed E.M.F. is at its maximum.

When opening a high tension circuit, the rise of potential will depend upon how suddenly the current is interrupted, and how much magnetic energy is stored in the circuit. This matter is treated by Steinmetz in the paper above referred to, and it is there stated that "The electric oscillations produced by opening a transmission line under load may reach destructive voltages, and the oscillations caused by interrupting a short circuit are liable to reach voltages far beyond the strength of any insulation." Also that "the voltages produced by the oscillations in opening a transmission line under load or under short circuit are moderate if the opening of the circuit occurs at a certain point of the E.M.F. wave. This point approximately coincides with the moment of zero current."

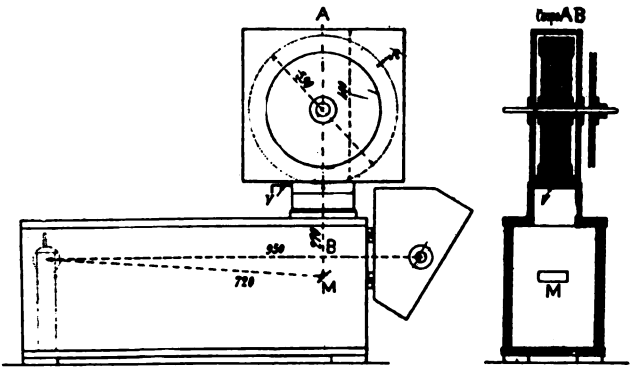

FIG. 1.

Electrical oscillations may be caused in electric circuits by resonance. In very few cases, however, in actual transmission and distributing circuits, can the rise of potential be attributed to this cause.

Among many papers dealing with the subject of surges on transmission lines, the only one so far giving the result of actual experiments recently appeared in the transactions of the Société Internationale des Electriciens. The paper is by Mr. Charles David, on Oscillographic Researches made by the Central Electrical Laboratory, Paris, on the High Tension Circuit of the Mediterranean Coast Power Co. This paper is very valuable, and the following abstract should prove interesting to the members of the Electrical Section of the Society.

The instantaneous values of E.M.F. and current were obtained by means of a Blondel-Charpentier oscillograph.

In the ordinary form of oscillographs, the images are obtained on a photographic plate 3.5" by 4.5". It was advisable to arrange

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some means by which the records would be taken for a time sufficient to include conditions not only during the period of surging but for the time before and after.

Instead of the ordinary plate, a film 3.5″ wide by 4.5 feet long was wound on a wooden cylinder (Fig. 1), placed in a closed box with a shutter and arranged so that the images on the galvanometer mirrors could be thrown on the film. This drum was rotated by a small motor, so that the width of a period length as shown on the film could be altered by speeding or slowing the motor. It was thus possible to obtain a large number of periods on one film.

The transmission lines experimented upon are shown in Fig. 1A.

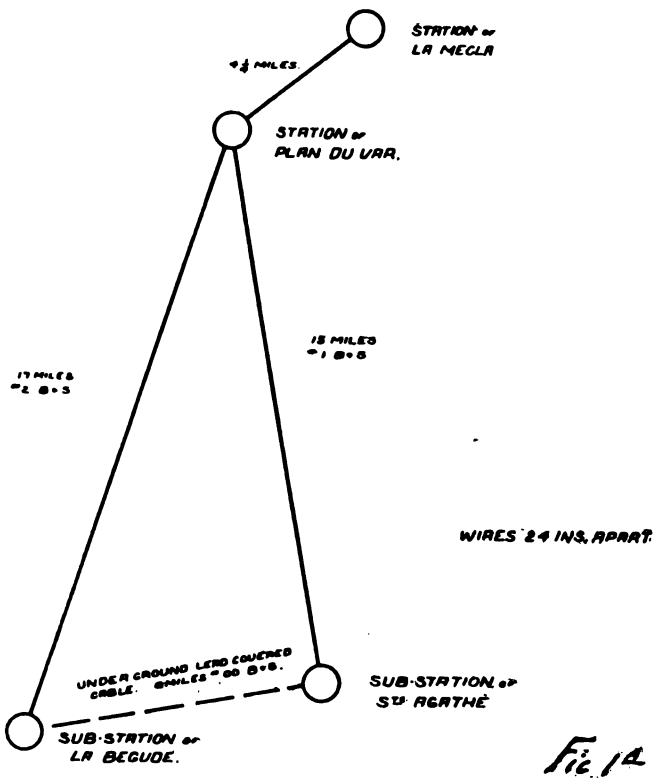

Fig. 1A.

The two stations of Plan du Var and La Mecla operate in parallel. These stations are 4½ miles apart. The line joining them is overhead, 3 phase, 3 conductors, 24″ apart, No. 1, B. & S. copper wires. From station of Plan du Var two overhead transmission lines, 17 and 15 miles long, go respectively to sub-stations at La Bagude and Ste. Agathe. The line to La Begude is made

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up of three conductors, No. 2, B. & S., 24" apart, and that to Ste. Agathe of No. 1, B. & S. conductors same distance apart.

The sub-stations at La Begude and Ste. Agathe are connected by an underground 3 conductor lead-covered cable 8 miles long, No. 00, B. & S. conductors.

Capacity in m.f. between one conductor and the other two connected to the lead covering, 0.825 per 1,000 feet.

Capacity in m.f. between the three conductors joined together and the lead covering, 0.825 per 1,000 feet.

It was thus possible to experiment with a circuit forming a loop of a total perimeter of 40 miles—32 miles of which were overhead, the remaining eight miles underground, the underground part about midway along the loop.

A 3 phase 600 K.V.A.—25 Cycle—11,000 volt alternator, driven by a 900 h.p. horizontal turbine, provided the electric power.

The switchboard in the station was equipped with high tension oil switches, and three pole air knife switches were also provided.

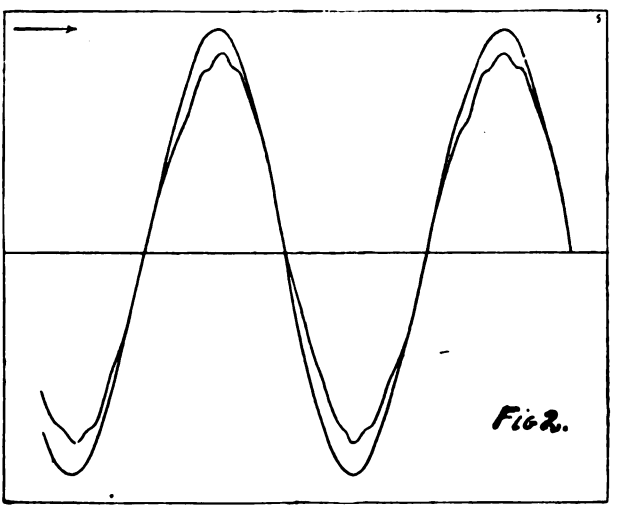

Fig. 2 shows the no load E.M.F. wave of the alternator, the machine giving an effective voltage of 7,000 at a frequency of 25. The sinusoidal curve is also shown.

In this particular E. M. F. wave. the effect of the fifth and seventh harmonics are the only ones noticed and they are quite small, the fifth being less than 2% of the value of the fundamental one.

The first experiments consisted in making and breaking with an air switch the charging current at the sending end of the line,

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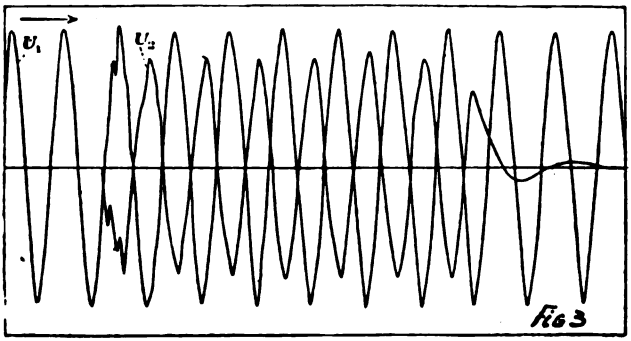
the charging current being approximately five amperes at 8,900 volts. The 40-mile circuit was unloaded but for a few transformers with open circuit secondaries which were left accidentally on the line.



In Fig. 3 U_1 is the E.M.F. wave across one phase at the generator, U_2 the voltage at the end of the line. Waves U_1 and U_2 have been shown in opposition of phase, that is, U_2 is displaced by 180° to show the two curves more distinctly.

The line is shown to have been switched on the busbars when the impressed E.M.F. is changing sign, and, as would be expected, the oscillations produced are very small. The oscillations cease in the first half period after the make. When the line is opened there are no oscillations on U_1, but the wave U_2 shows at the rupture a damped oscillation of large period.

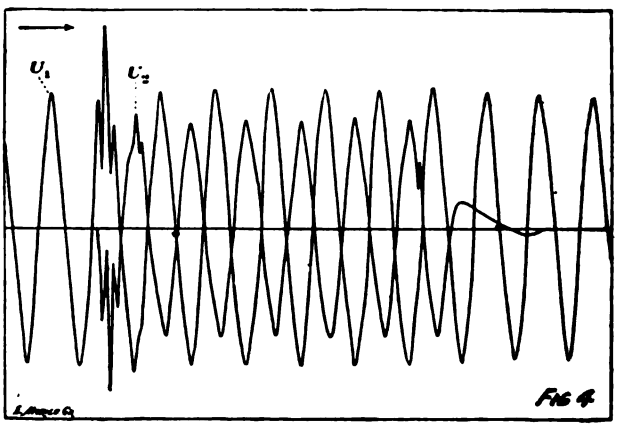


Fig. 4 shows the line switched on at the moment when the impressed E.M.F. is near one-fourth period.

At first the impressed E.M.F. is suddenly reduced, but further

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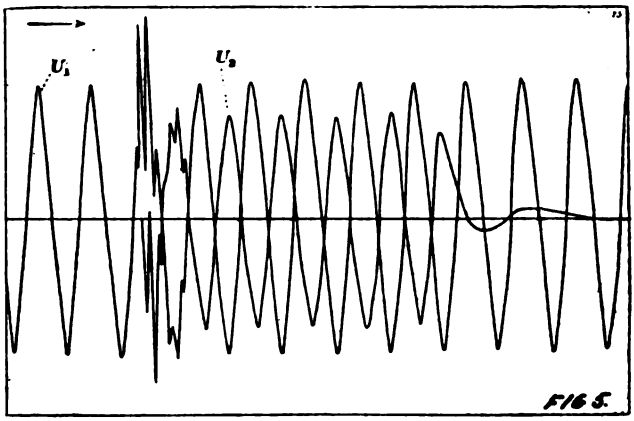
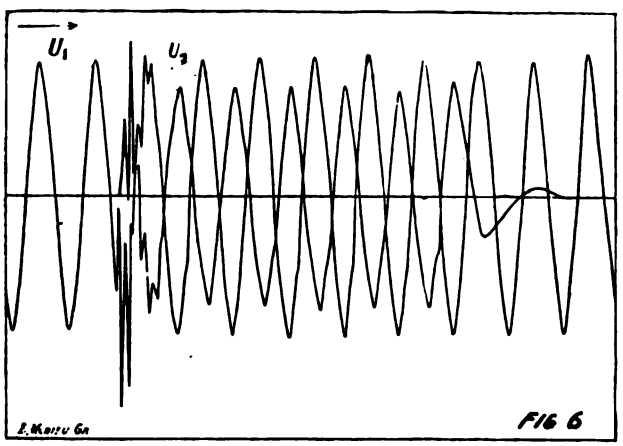
a rise of potential takes place, giving a 50% increase of impressed pressure. A rise is also shown on wave U_2. The oscillations cease in the first period after the make. Here, again, there are no oscillations in the impressed E.M.F. waves when the circuit is opened. but U_2 shows a momentary surge.





Figs. 5, 6 and 7 show the conditions of U_1 and U_2 when the line was switched on at the moment when the impressed E.M.F. is at or near one-third, one-half, and two-third period. The surges on both U_1 and U_2 are well shown and are quite large. The rise of potential, however, did not in any one of a large number of

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experiments exceed 55%. The oscillations take place in one period after the make of the switch. When the switch was opened the voltage never rose, but in all cases the wave U_2 shows a much longer period and is damped out in a single oscillation.

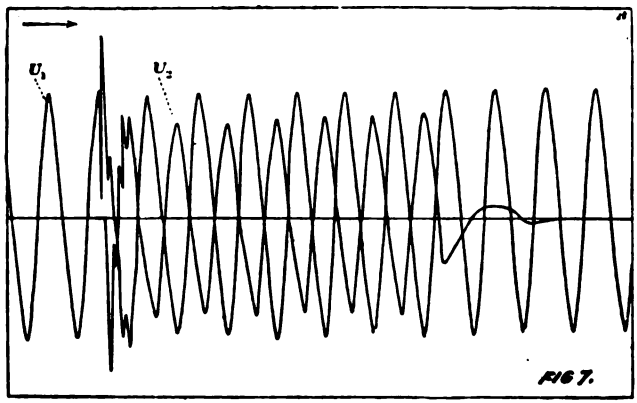

FIG 7.

The percentage of the number of times in which surging appeared to the total make and break equalled 66%.

Records taken on the unloaded line, when operated with an oil switch in place of the air switch, do not differ very much from those just shown.

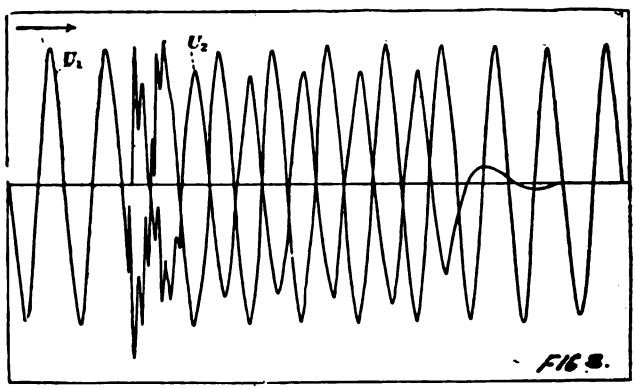

FIG 8.

Fig. 8 shows the value of U_1 and U_2, the unloaded line switched in with an oil switch at the moment when the impressed E.M.F. is near one-half period. The rise of potential for U_2, which for the air switch (Fig. 6), was considerable, 50% as near as can be

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judged, is only about half of that amount. U_2, although it shows considerable oscillations, shows no rise of potential.

Fig. 9 is for a similar load, but the time of switching is near the maximum value of U_1. The rise of potential is 60% for U_1 and 58% for U_2. This is somewhat greater than that obtained with the air switch under similar conditions.

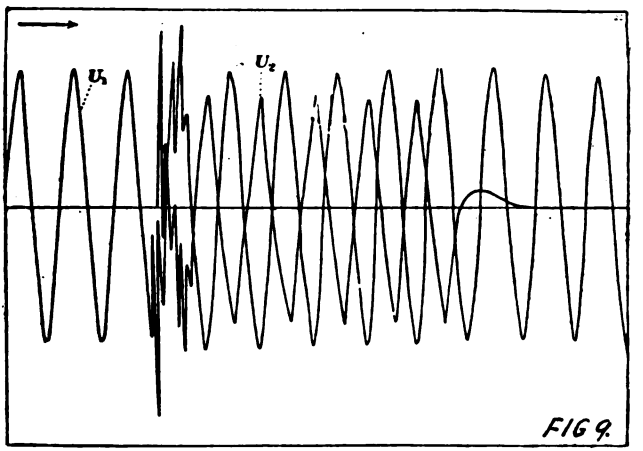

FIG 9.

At the opening of the circuit there are no oscillations or rise of potential in U_1 as for U_2. A damped oscillation of long period takes place in every case.

In twelve different experiments, the rise of voltage for U_1 and U_2 is as follows (line switched in):—

U_1 (E.M.F. at busbars)	one	rise of potential	64%
	two	" "	60%
	one	" "	50%
	three	" "	25%
	one	" "	18%
	two	" "	10%
U_2 (difference of potential at end of line):			
	one	rise of potential	67%
	two	" "	64%
	one	" "	58%
	two	" "	30%
	one	" "	25%
	two	" "	17%
	one	" "	8%

So far as these experiments go, there is not very much differ-

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ence whether an oil or an air switch is used. Whenever the switching in takes place when the impressed E.M.F. is near zero, the rise of potential will be very small. At other times the rise of potential will be considerable and violent oscillations will be set up, disappearing in one period. At the break no rise of potential under any conditions has been noticed.

EXPERIMENTS WITH NON-INDUCTIVE LOAD, OIL SWITCH.

Oscillographic records are given for: first, the switch placed between the generator busbars and the line; second, switch placed

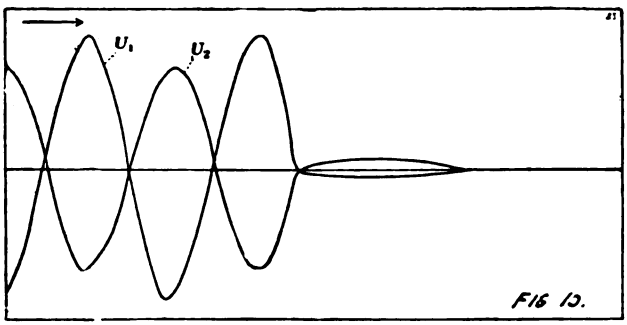

FIG 10.

between the line and the load. A three phase water rheostat was placed at the end of the line as a load.

The experiments under load were carried out in the following manner. The alternator was loaded through the 40-mile line on the water rheostat. The switch was then opened for one-half second and then closed. The load was adjusted to 22 amperes, a voltmeter on the line side of the switch reading U_1 (7,200 volts on one phase) and a voltmeter placed on the rheostat reading U_2 (6,200 volts).

SWITCH PLACED BETWEEN GENERATOR BUSBAR AND LINE, OPENING OF CIRCUIT.

Fig. 10. The opening of the switch is shown to have taken place when U_1 is zero. No rise of potential. Other records show similar result. The break is always shown to take place at zero value of impressed E.M.F. Mr. David is uncertain as to whether this is due to the oil switch or pure hazard.

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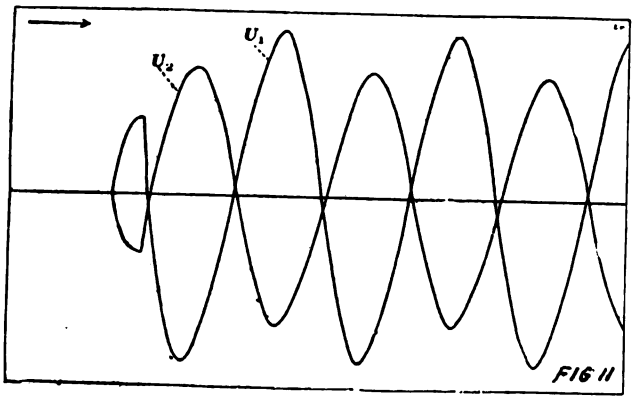
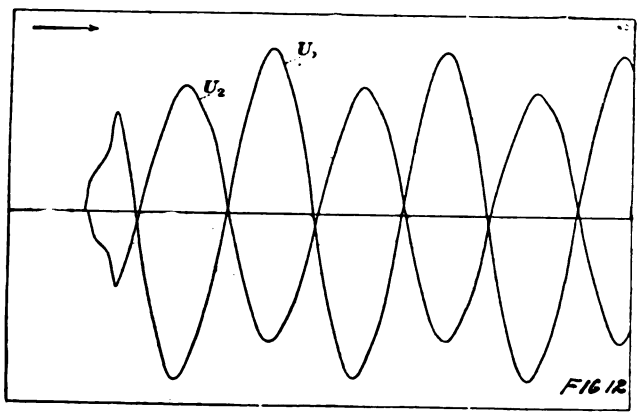


In Figs. 11 and 12, waves U_1 and U_2 are shown when the switch is closed. There is no surging or rise of potential. The regime is steady after the first period following the close of the circuit.



HIGH TENSION OIL SWITCH PLACED AT END OF LINE.

The oil switch was placed between the receiving end of the line and the rheostat, so that the alternator was kept on the line when the load was switched off.

SWITCHING IN.

In Fig. 13, U_1 and U_2 are respectively the E.M.F. of the generator and the difference of potential on the line side of the switch (U_1=7,300 volts, U_2=6,100 volts, the current 26.5 amperes). Oscillations are shown on U_1 and U_2, but without rise of potential.

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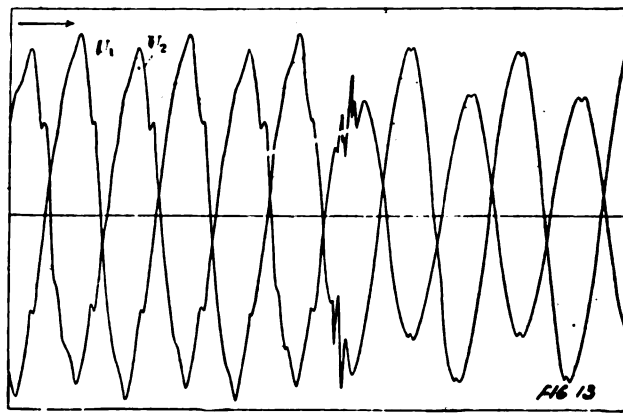
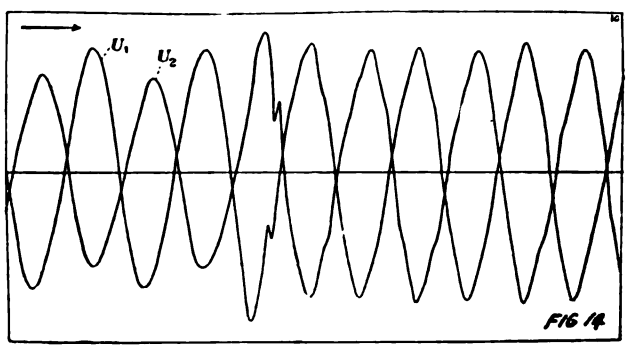


Fig. 14 gives values of U_1 and U_2 when the switch is opened. The rise of voltage on U_1 is 24% and 18% for U_2. Oscillations take place in the time of the period corresponding to the unswitching. In the course of a large number of experiments under similar conditions of load no rise of potential ever took place at the switching



in. At the unswitching, however, the increase lies between 15% and 24%. The percentage rise of potential is usually greater at the sending than at the receiving end.

AIR SWITCH.

Experiments were carried on with an air switch, this switch being of special make, allowing the arc made at the break to rise between copper horns, increasing the length of the arc until it broke. The records show that the rise of potential with this switch is considerably greater than with the oil switch under similar conditions of load and that the oscillations are kept up for at least two periods after the opening of the circuit.

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EXPERIMENTS WITH AN UNDERGROUND CIRCUIT.

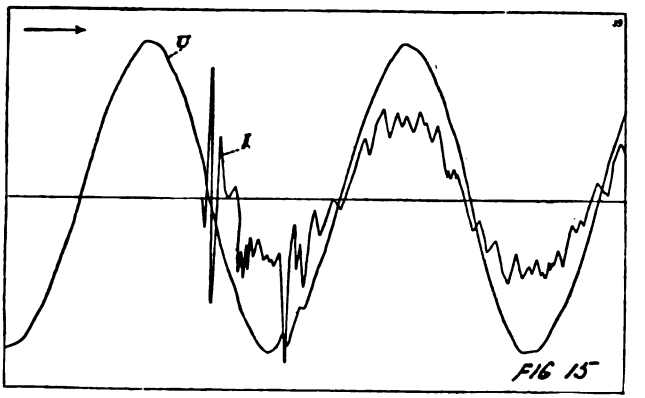
The cable experimented with, is a three conductor lead-covered cable, four miles long.

The cable unloaded was switched on the busbars through an oil switch, and records of E.M.F. and current are shown in Fig. 15.

The busbar voltage was 9,700. The current value is not given but could not be more than a few amperes.

In Fig. 15, U the E.M.F. wave shows little oscillations, not so with the current wave I. Rapid oscillations take place during the first half period corresponding to the closing of the switch.

A 200 kilo-volt-ampere transformer with secondary winding open was then connected to the end of the cable.



Watt transformer input 4,500; applied voltage 9.600; the current is not given.

Fig. 16 shows cable switched on when the impressed E.M.F. is about changing sign. The E.M.F. wave shows no oscillations. The current wave shows violent ones. The maximum values of the current exceeded the width of the film and are not recorded on this plate. The negative and positive waves are dissimilar and the distances between the zero values are unequal. The switch was opened after an interval of four periods, the current had not then taken its normal value.

Fig. 17 shows E.M.F. and current waves for a similar test, but the switch closed at one-third period. Small oscillations are shown on the E.M.F. wave. The current wave is again very erratic, starting with a large rise of current, followed by a series of rapid oscillations. The circuit was opened at the end of the eleventh period,

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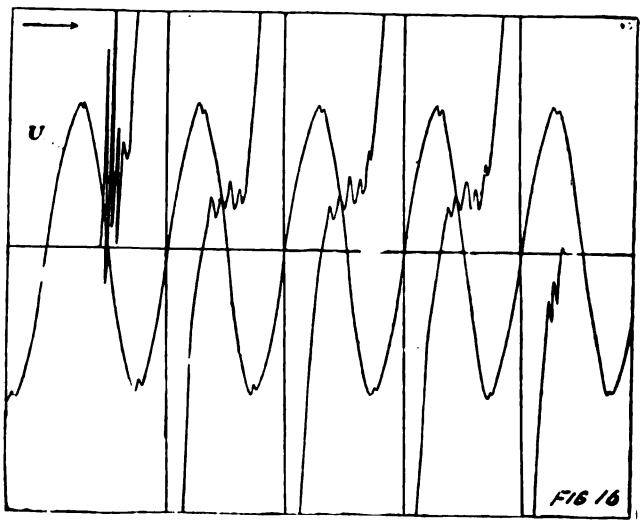
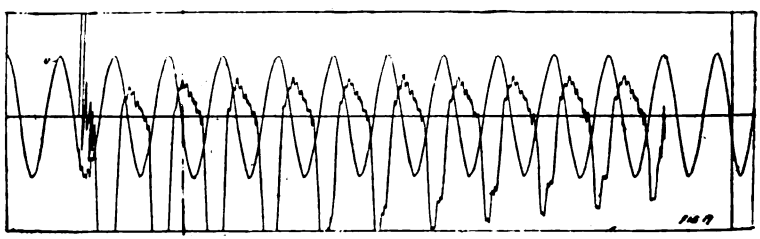


but the current had not taken its normal value. The effect of the unswitching is shown by a small oscillation of the E.M.F. wave.

A number of experiments were taken and show similar



results. In all cases it is shown that the E.M.F. wave suffered very small disturbance at the closing or opening of the circuit, but the current waves show violent oscillations.

These experiments are not sufficient to arrive at definite conclusions, but they show that there is a danger of overvoltage when a transmission line is thrown on generator busbars except when the switching in is done at or near the moment when the impressed E.M.F. is zero; there is no danger of overvoltage when the line is switched off, the charging current being usually small.

There is danger of overvoltage when a loaded line is switched off the high tension busbars and the oil switch is likely to prove less dangerous than the air switch.

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MECHANICAL SECTION.

President—R. J. DURLEY.
Vice-President—G. J. DESBARATS.

A meeting was held on Thursday, November 16th, Mr. R. J. Durley in the chair. Mr. Harrington read the following paper:

PAPER No. 232.

THE WHARF CRANES OF THE PENNSYLVANIA RAILROAD COMPANY AT GREENVILLE, N.J.

By JOHN LYLE HARRINGTON, M. Can. Soc. C. E.

The great industrial development of the last century was accompanied and largely made possible by co-ordinate growth in the facilities for both foreign and domestic transportation. Within that period the railway became the most important single factor in the material life of all progressive nations, and the steamship relegated to a secondary place the sailing craft which had been for all the preceding centuries substantially the only means of carrying on the foreign or domestic commerce.

The traffic carried by the railways and the merchant-marine of the world has assumed almost incomprehensible proportions, but the development of the means for transferring goods from one great carrier to the other has not kept pace with the demand. The mast and gaff, operated by the ship's winches, and the hand truck still remain the chief means for handling package freight, though the greater steamship lines have very recently equipped their wharves with electric hoists to operate the mast and gaff.

The handling of iron ores, however, has received the attention of many of our ablest engineers during the last third of a century, and the traffic in iron ore now existent upon the great lakes is only made possible by the improved facilities for removing the ore from the vessels and delivering it to railway cars cheaply and with dispatch.

The handling of coal, especially in the seaboard cities, has also received the attention of specialists, and the machinery for this work has reached a high state of development.

This rapid and economical handling of ores, fuel, and flux has greatly reduced the cost of iron and steel, and thus exerted incalculable influence upon the world's industrial growth.

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Cranes for handling package freight have been sporadically developed, here and there, for handling very heavy loads. The most notable of these are the cranes used by the great navies for the trans-shipment of heavy guns. But the greater portion of the package freight is still handled by comparatively primitive means. The cost of trans-shipment is great, and the earning power of vessels and cars is considerably reduced because they are idle during the time required for loading and unloading cargo.

Both the railway and the steamship companies are rapidly reaching the conclusion that they must make the necessary expenditure for freight-handling machinery, if the work is to be done economically and quickly. About two years since, when the Pennsylvania Railroad Company began the construction of its new freight terminus in the New York harbour at Greenville, N.J., they invited various engineers and builders of prominence to submit designs for cranes, to be operated by electricity and to handle freight, both bulk and package, between the railway cars and the vessels.

In response numerous carefully thought out designs were submitted, and the engineers of the various companies tendering exposed very fully the methods of operation and construction proposed and their advantages. The Railroad Company's engineers made a minute and careful examination of these plans, visited and examined in operation various installations of hoisting machinery employing the principles embodied in the designs offered, and made a report which resulted in the selection and purchase of the three cranes described below.

By the initial arrangement there were to have been two cranes of one type designed primarily to handle loose freight, such as coal, broken stone, sulphur, and iron ore, in bulk, the third crane being of larger capacity and especially designed to handle heavy package freight; upon further study of the situation, however, the plan was modified so as to combine in one type of crane the more desirable features of both.

The cranes, as constructed, embody the best thought of the manufacturers' engineers, ably aided by the advice and suggestions of the engineers of the Pennsylvania Railroad Company, and, it is thought, represent the most advanced type of construction yet developed for the purpose.

GENERAL DESCRIPTION.

The illustrations presented herewith expose the principal features of the cranes, but there are many details of large importance

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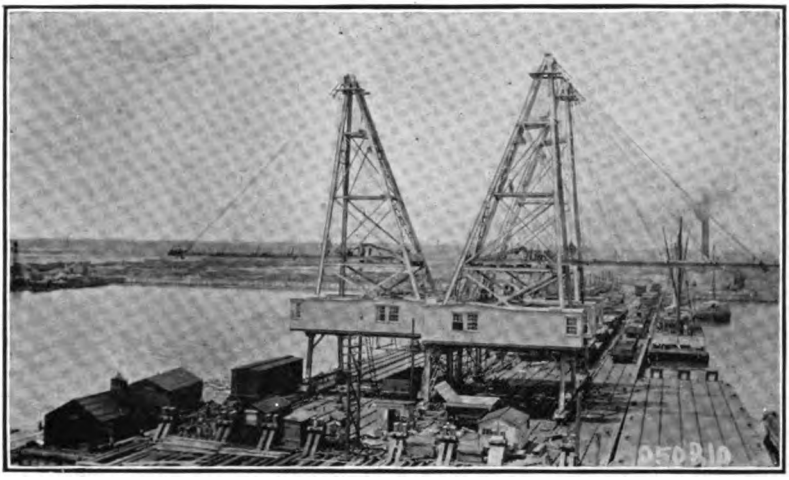

FIG. 1

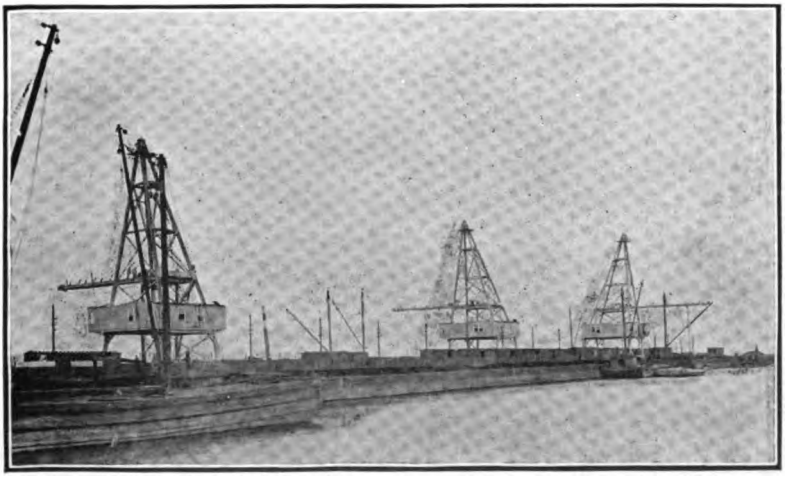

FIG. 2

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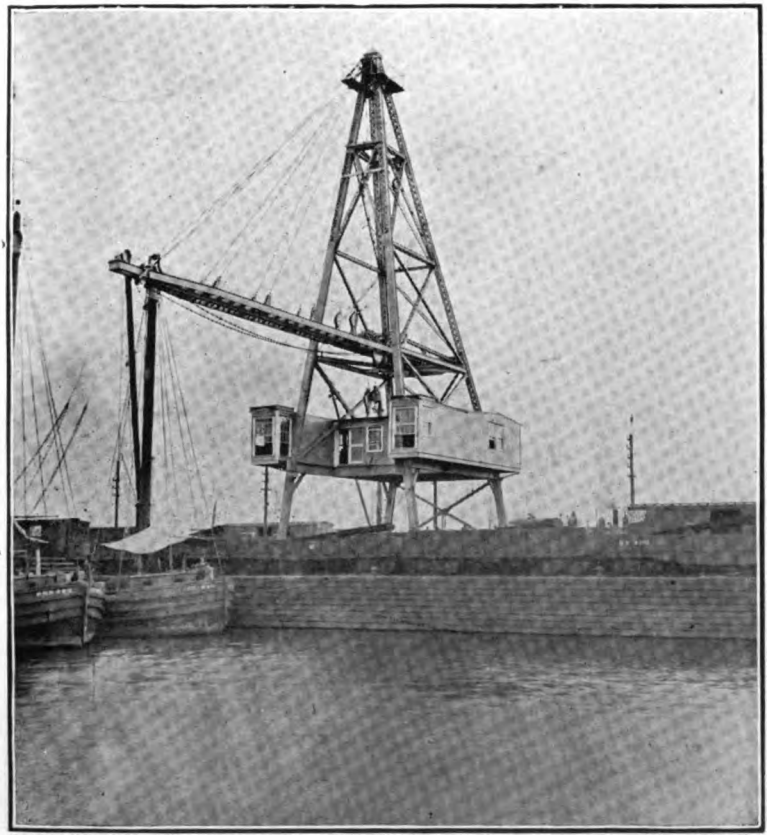

FIG. 8

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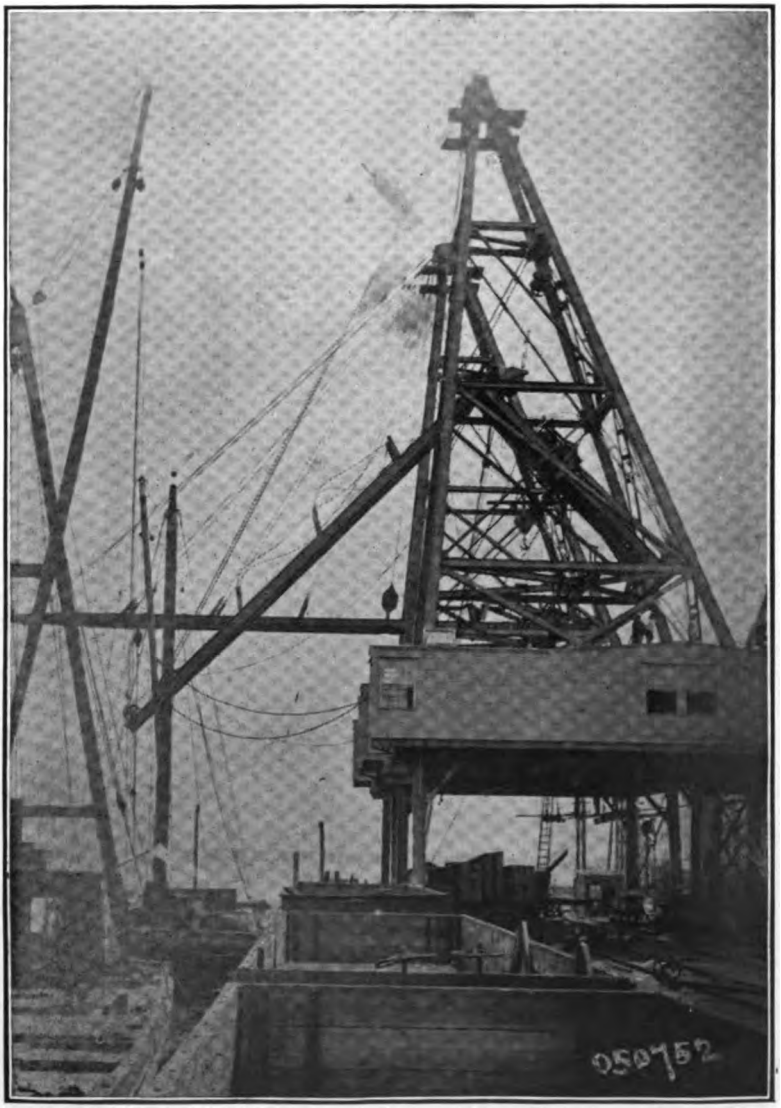

FIG. 4

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and brakes are led to the operators' stands, where the controllers are also placed. The operator who controls the movement of the boom also controls the movement of the cranes along their tracks.

The cranes are amply provided with electric lights both for the engine room and for illuminating the pier and vessels for night operation.

Each crane is provided with a telephone for communication with the other cranes or with shore connections.

DETAILED DESCRIPTION.

The steel framework is designed and constructed in accordance with the Pennsylvania Railroad Company's specifications for railway bridges, in so far as they are applicable to a structure of this type. A very substantial and rigid floor system supports the engine house and takes up the vibrations of the machinery. The house itself is constructed of wood with a double floor in the ordinary manner. Access to the engine house and to the sheaves at the top of the tower is obtained by means of a ladder, shown in Fig. No. 3.

Each truck is composed of four standard chilled car wheels of the heaviest type, standard 5 x 9 journals, journal boxes and bearings, and a steel frame composed of heavy 15" channels, substantially braced. Two of the trucks are provided with air brakes, as shown in Fig. No. 10, the brakes being operated from the engine house. Each of the other trucks is fitted with a 25 h.p. railway type motor and cut spur reduction gearing for operating the crane on its tracks, as shown in Fig. No. 8. The driving trucks are also provided with double rail stops which are suspended from the body of the truck when the crane is in operation, but which are let down on the rails between the wheels when the crane is not in service. The large surface exposed to the wind would enable a very light breeze to move the crane along the tracks, but after a very slight movement two pair of wheels mount these stops and prevent further travel in either direction. All the trucks are articulated in two directions, hence a proper bearing on the tracks is always assured, no matter what the condition of the pier may be.

The main hoisting engine, which is illustrated in Figs. Nos. 5 and 6, is designed either to handle the package freight on a one, two, or three part rope, or to operate the clam shell bucket, for which two ropes are, of course, required. It is fitted with a solenoid brake and with an exceptionally large and efficient load brake, which absolutely prevents the load from running down in case the current should be cut off or accident should happen to the motor. A small drum attached rigidly to the shaft, as shown on the near

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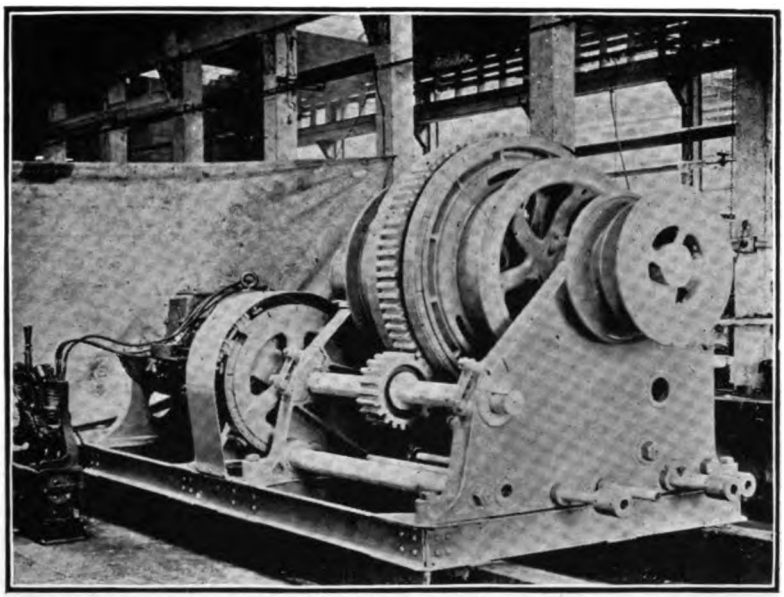

FIG. 5

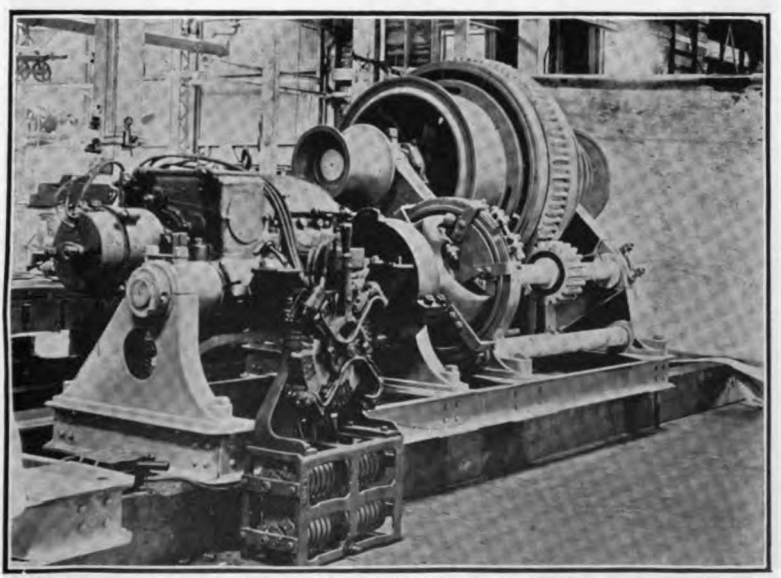

FIG. 6

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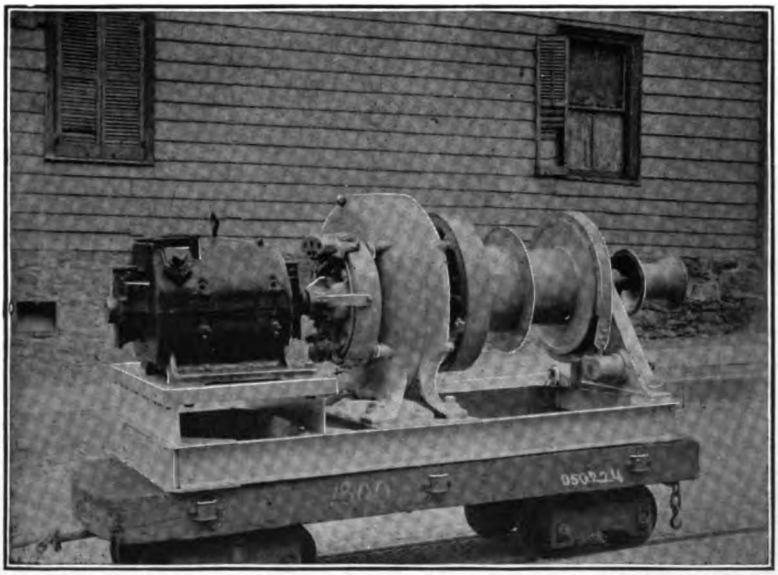

FIG. 7

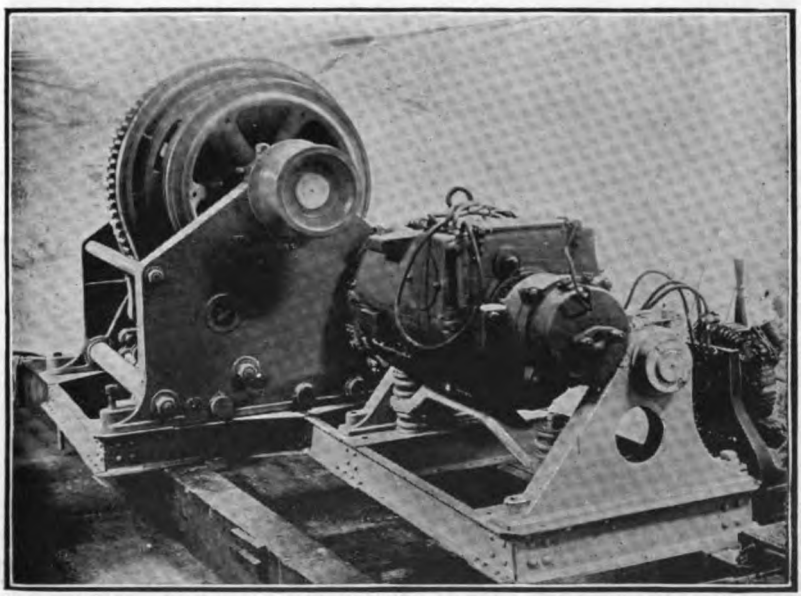

FIG. 8

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end in Fig. No. 5, is used to fold the boom. Each of the main hoisting drums is fitted with a conical friction clutch and a band brake, and consequently is under full control of the operator. A 100 h.p. motor wound for 500 volts direct current and mounted on springs, much as it would be on a railway car, operates the engine.

For hoisting package freight but one rope is used. This is led from one of the drums directly over a large sheave in the head of the tower, thence over the outer of the two boom truck sheaves, around the sheave in the running block, over the inner sheave on the boom truck, and then attached by a shackle to the running block, as shown in Fig. No. 11. Obviously a single or double part rope may be used for rapid work with light loads.

When the clam shell bucket is employed the main hoisting rope is operated by one drum, and the closing rope, which also assists in the hoisting, by the second drum. These ropes also lead over the sheaves in the head of the tower, thence over the sheaves in the boom truck, and connect to the bucket.

The boom truck is fleeted outward along the boom by means of the engine shown in Fig. No. 7. The drum is divided into two parts, one of which is somewhat larger in diameter than the other. When the clam shell bucket is in use a single rope leads from each part over sheaves supported in the rear of the boom, thence over the sheaves at the outer end of the boom, shown in Fig. No. 4, thence to their connections on the boom truck. The rope attached to the larger part of the drum is connected to the outer end of the truck, and the other rope to the inner end. Thus the outer pair of wheels and sheave are drawn out more rapidly than the inner pair and sheave, and the truck spreads as it approaches the end of the boom. Longitudinal bars connect the two parts of the truck but permit this extension. This movement of the sheaves in the boom truck separates the hoisting ropes and prevents the clam shell bucket from turning and twisting the ropes as it enters or leaves the hold of the vessel, yet permits the hoisting ropes to come together as the bucket approaches the boom in its parabolic path.

When package freight is being handled, but one trolley rope is employed and the parts of the truck do not alter their relative position as they traverse the boom.

The engine is operated to draw the truck toward the end of the boom, while the horizontal component of the hoisting ropes brings the truck in toward the tower when the clutch and brake are released. The engine may, however, be operated to draw the truck to its inmost position if desired. This engine is also fitted with solenoid and load brakes. The reduction gears are enclosed in an oil-tight case, have cut teeth, and run in a bath of oil.

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Fig. No. 8 illustrates the third engine employed to operate the auxiliary hoist for placing slings under the loads of package freight. The hoisting rope is led directly from the engine to a sheave in the rear of the boom, thence forward to a block suspended by a slide from the underside of one part of the boom. The rope is then led around the running block in the usual manner. This slide is moved along the boom and held in any position by a continuous rope running over sheaves at both ends of the boom and operated by the winch head on the engine. The engine is also operated by a 25 h.p. railway type motor mounted on springs. The hoisting drum is controlled by a conical friction clutch and band brake in the usual manner.

The construction and operation of the crane boom merits especial attention. It consists of two symmetrically disposed parts, each composed of an I beam and a channel well braced together. The parts are rigidly connected at the ends, but throughout the traverse of the boom truck are separated to admit the passage of the hoisting ropes. The truck runs on rails placed directly upon the I beams. As shown in Fig. No. 3 the boom extends to the extreme rear of the tower where the horizontal thrust due to the weight of the boom and the tension in the trolley ropes is carried by a heavy girder. The guy ropes always occur in pairs in order that the hoisting ropes may traverse the length of the boom between them, and they are so attached that the respective halves of the boom are balanced under load and do not twist. They are provided with turnbuckles near the head of the tower for adjustment.

The boom is hinged for vertical movement at the rear and at a point just forward of the front legs. This construction permits the boom to be folded to clear the vessel's rigging, as shown in Fig. No. 4, by means of blocks attached to the outer boom hinge and to the tower near its head and falls operated by the small drum on the main engine. The position of the outer hinge is so chosen that but slight additional weight is required to cause the boom to resume its normal position when the hoisting ropes are released. This additional weight is supplied by the boom truck which, when the boom is folded, lies in a pocket formed by bent ends of the rails on the rear of the boom, and by the forked brace at the rear, as shown in Fig. No. 4. The brace is hinged at the rear, and the centre line of its hinges is made to coincide with that of the horizontal rear boom hinge, in order that the brace and hinge may rise together without friction. The brace is so supported on the bracing of the tower that it does not follow the boom to a horizontal position, but remains about four feet above. The vertical forks at the

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FIG. 9

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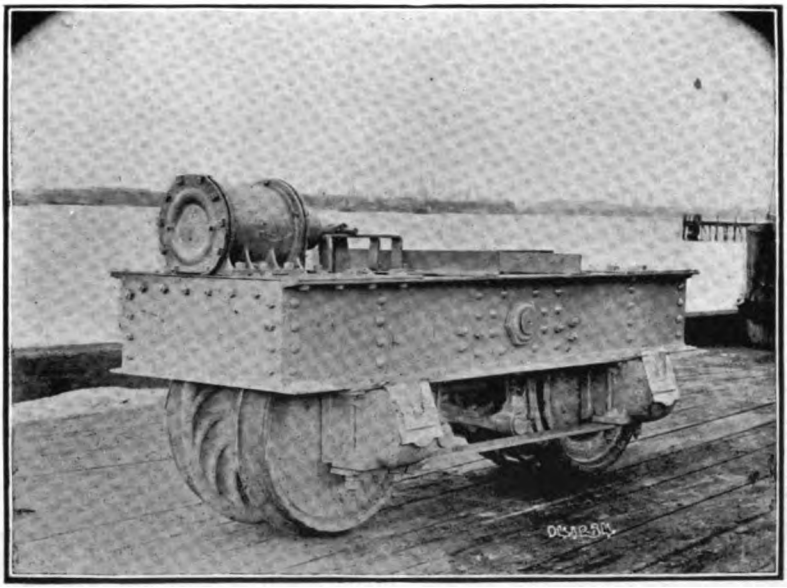

FIG. 10

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FIG. 11

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end, however, always project below the boom, and, since they flare downward, guide it to a central position as it rises, though they permit its free lateral movement when the crane is in operation. The action of this brace is evident from an examination of Figs. Nos. 1 and 4. The brace prevents the boom from turning over when being folded, as it has a tendency to do, since the centre of gravity is well above the points of support. At the extreme rear the boom is hinged in two directions, so that it is free to be folded and to swing sidewise in either direction within the range permitted by the front legs of the tower.

The boom is supported entirely by the wire rope guys and on a combined vertical and horizontal hinge at the rear. This arrangement permits the boom to swing freely when a load is being lifted from a point not directly beneath it, minimizes the effect of the shock from the accidental dropping of a load, and substantially eliminates the danger of damage from collision between the masts of a vessel and the boom. Lateral guy ropes limit the horizontal movement of the boom when it reaches the opposite front leg of the tower.

The removable hopper is so designed that it may be lifted by the crane and dropped into its working position. Bulk freight may be delivered from it into cars on the track in front of the crane or the first track beneath it. This material may be weighed as delivered if desired.

A water main is carried along the entire length of the pier just beneath the floor, and at intervals hose connections just above the floor are provided. Each crane is provided with two universal nozzles, one on top of each front corner of the engine house, from which duplicate pipes lead to the middle of the strut connecting the rear trucks, where coupling is made by means of flexible hose to the couplings on the pier. Thus each crane is made a veritable fire engine.

The cranes were designated to operate on their tracks at a speed of about 180′ per minute under the greatest estimated resistance. The motors are, however, under series parallel of control and operate together at full or half speed. The resistance is normally far below the maximum, consequently the speed of operation is commonly much greater than 180′ per minute. In fact, the mobility of the cranes is astonishingly great. On this account it has, in operation, been found more advantageous to move the crane over the load and place the slings with the main hoist, than to employ the auxiliary hoist for that purpose. The leading of the hoisting ropes over the head of the tower and thence over the boom truck, which is never under full load, greatly facilitates the ease and rapidity of operation and greatly reduces any shock caused by

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the slipping of a load. The suspension of the boom proves to be extremely advantageous. One of the cranes has been so violently struck by a vessel that the boom was forced to its extreme position and the tower itself twisted until some of the trucks left the tracks, but, owing to this extreme flexibility of the boom, the resultant damage was negligible.

The operation of the cranes as a whole has been eminently satisfactory to both their designers and builders and to the Railroad Company. They are large and expensive machines, but they have so thoroughly demonstrated their merits in the few months they have been in operation, that, in future, there is little doubt that similar machinery will be employed on all large wharves. The resultant economy in handling the freight and in the dispatch of vessels makes the installation of such machinery on all important wharves eminently advisable.

The cranes were designed and constructed by the C. W. Hunt Company, of New York. Although the plans were prepared under the author's direction, the design is the result of the combined work of Messrs. C. W. Hunt, C. C. King, Wm. Seaton, W. D. Stivers, and the author, ably assisted by Messrs. A. W. Gibbs, Genl. Supt. of Motive Power, his assistant, Mr. B. F. Wood, and Mr. A. S. Vogt, Mechanical Engineer, of the Pennsylvania Railroad Company.

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DISCUSSION.

Professor R. J. Durley regretted that Mr. Harrington had not gone rather more into detail, and touched on such questions as the expense of operation and cost of handling material by means of the cranes described. He did not know whether any tests were made on the Greenville cranes or not, but was reminded of a paper, read at the joint meeting of the American Society of Mechanical Engineers and the English Institution of Mechanical Engineers last year at Chicago, on the Comparative Cost of Working Electric and Hydraulic Cranes at Middlesboro, Eng. These cranes were, of course, of a different type, but figures were given as to the cost of handling material, and as to the expenditure of electric energy. Similar data from Mr. Harrington would be most valuable. Prof. Durley.

In answer to a question from Mr. Goldmark, Mr. Harrington explained that there were two operators, one handling the engine which operated the boom truck, the other caring for the main hoisting engine. One man alone could not manage the simultaneous movements, especially in the handling of a clam shell bucket. With an ordinary crane, there was one less drum to handle. In operating a clam shell bucket, there were thirteen movements, so that one man was kept exceedingly busy with the hoisting engine alone. Mr. Harrington.

Mr. John Kennedy remarked that it was astonishing how two men could so exactly co-ordinate their movements as these operators did. It was very interesting, for instance, to watch the clam shell coal derricks in the Montreal harbour, which were operated in this way. The clam shells were literally thrown into the hatches of the steamer, making trajectory, which was the component of vertical and horizontal motions controlled by separate operators, and they were thrown with such accuracy that they seldom struck the sides of the hatches. Very skilful operators could sometimes make as many as six trips a minute, and nearly all could work steadily at the rate of four trips on a lift of seventy feet and a horizontal movement of nearly forty feet, each clam shell raising an average of 150 tons of soft coal per hour, inclusive of the time for cleaning out the hold. Mr. Kennedy.

The Greenville cranes had evidently been designed for the special work of transferring large lots of one kind of freight directly between the cars and the vessel without the intervention of a shed, and seemed well adapted for that purpose. They had

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Mr. Kennedy

mechanical movements that were unusual and greatly enhanced their value, making them, in his opinion, the most complete in the ports of this continent or Europe. As to the crane problem for handling cargoes of miscellaneous goods there were many complications. In ordinary cargoes, the consignments were packed in the hold with the main idea of fitting well. One package would come out for Chicago, the next for Ottawa, another for Winnipeg, etc., so that practically they could not go into the cars directly, consequently a shed was necessary. Customs House regulations and other considerations also involved this necessity. Goods making up out-going cargoes had to be received in such order as they might happen to arrive and had to be stored until the ship or particular hold was ready to receive them. On this continent there were practically no railway tracks between the shed and the ship, and in order to save space and distance of handling cargo, the shed was put as close to the side of the wharf as possible. This made it possible to handle the goods between the ship and the shed entirely without wharf cranes. In British and European ports the conditions were quite different. There the railway cars or trucks were small and light and easily handled. A car could be shoved along by men or horses, turned on a 12½ ft. turntable and pushed out of the way with almost as much ease as a large dray. As little as a ton or a ton and a half was accepted as a carload. The trucks were practically all open, being merely covered with tarpaulins, and therefore easily loaded from overhead cranes. These conditions had led to the placing of one track, or more commonly, two or three, or even four, between the ship and the shed, and wharf cranes were therefore a necessity for the handling of goods between the ship and the shed, and for loading and unloading cars on the space between. These were commonly light swinging cranes mounted on overhead moveable frames which straddled the railway tracks. The older cranes were nearly all hydraulic but many of the newer ones were electric. The lifting capacity was ordinarily about three tons, but in some ports as high as five tons. The conditions which governed the handling of cargoes on the two continents were therefore entirely different, growing largely out of the great difference in the railway cars, and so it came that general merchandise cargoes which were handled almost wholly by cranes on one side of the Atlantic were handled without them on the other.

The Greenville cranes were well adapted where the consignments were large and handled direct, but they would not be suitable for the ordinary general cargoes.

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Mr. Harrington. Mr. Harrington replied that the main purpose of the cranes was for handling large shipments, such as steel rails, lumber, etc. As an example of the saving in expense of handling by the use of machinery, at Port Tampa, Florida, a bonus was offered for quick loading and delivery of large shipments of phosphate rock. Machinery was put in by the Plant Line at that point, and the bonus earned in one year entirely paid for the installation.

In reply to questions from Professor Durley, Mr. Harrington said that the speed for hoisting was less than with a steam engine, as there was only a 100 h.p. motor which operated the crane with full load at about 110 feet per minute. 420 feet per minute was obtained from a clam shell bucket. Considering the all round use of the towers, it was thought best not to have a faster rate. The number of trips that it was possible to make depended upon the facility with which slings could be attached and the truck could be run in and out, rather than on the direct hoisting, which was a smaller part of the work. In the majority of cases the crane must be moved and the load attached before hoisting began. A clam shell bucket made about three trips per minute, but with a directly connected steam hoist, about four trips per minute, so that the electric apparatus was somewhat slower. With regard to the difference in handling coal or ore by a crane of this type and by the ordinary jib crane, it was rather difficult to say. The Boston tower did very rapid work. There were some of these in use in Montreal and they were, of course, very numerous throughout the United States. The Parabolic Boom Hoist, also developed by the Hunt Company, required only one man to operate it and did very good work. In answer to Mr. Kennedy, Mr. Harrington said that most of the freight was loaded on open cars and the small packages which were loaded in box cars were simply swung in while suspended in the air. There were two rails to each track, 14 inch gauge. The tracks were made exceedingly narrow as the available space on the wharves was limited.

Mr. H. Goldmark. Mr. H. Goldmark asked if any estimates had been made comparing this type with the overhead superstructure or runway.

Mr. Harrington. Mr. Harrington answered that the latter type would not be feasible on account of the rigging of the vessels. The longitudinal movement of the cranes was not obstructed by the rigging. It was necessary to move sometimes about half a car length, owing to the exposed position of the cranes. The runway would also be liable to trouble from the wind.

Mr. H. Goldmark. Mr. H. Goldmark asked if the cranes were equipped with any means of moving the cars.

Mr. Harrington. Mr. Harrington replied that a car could be drawn by blocks and tackle operated by a winch-head on the engine, but the crane

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could move more quickly than it could move the car, and the freight was handled so rapidly that there was always a switch engine present to switch cars. In answer to a question from Professor R. J. Durley, Mr. Harrington said that the two cranes could be worked at hatches about forty feet apart.

Mr. Goldmark. Mr. Goldmark wished to know how many rails the crane could handle at one time, and if they had to come out endways.

Mr. Harrington. Mr. Harrington replied that they would handle up to their capacity, and cranes were being designed which would take out a whole carload at once and load it. The rails were usually handled with two slings attached to one block, and one end of the sling was longer than the other. The booms would operate fifty-two feet from the edge of the wharf so that they could discharge over the outside of any ordinary ship to load a barge.

In conclusion, Mr. Harrington wished to point out the advantage of the trolley type of crane, especially where the ropes were at the end of the tower. Any slippage of the load produced no effect on this crane, but with the rigid type the jar was very heavy when the load surged. The flexible movement in the lateral direction was very helpful. These cranes could be operated at a low or high rate of speed by the control of the driving motors. The means for preventing the crane from running away might seem extraordinary, but serious accidents due to the wind blowing cranes along the track were by no means unusual, hence perfect means for prevention were necessary.

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MINING SECTION.

President—J. B. PORTER.
Vice-President—H. C. BURCHELL.

A meeting was held Thursday, November 30th, 1905, Dr. J. B. Porter in the chair. Two papers were read by Dr. Porter and one by Mr. J. F. Robertson, as follows:

PAPER No. 233.

THE TESTING OF EXPLOSIVES USED IN ENGINEERING.

By J. B. PORTER, D.Sc., M.Can.Soc.C.E.

The advantages to be gained from the possession of a satisfactory method of testing and comparing explosives have long been appreciated by engineers, and during the last three centuries a very great number and variety of gauges and other devices have been invented and used, chiefly by gunnery experts. Some of these devices are admirably ingenious, and by their means very accurate investigations have been made, not only of gunpowder and similar low explosives, but even of the various high power smokeless powders, such as cordite, etc., which now form so large a part of both military and sporting ammunition.

Nearly all the work that has been done thus far has been on powders intended for ammunition for guns great and small, or for the guidance of the manufacturers of explosives; and engineers engaged in rock excavation for railway, mining, and other purposes are still supposed to be without any simple and reasonably accurate means of determining by small tests the comparative efficiency of the explosives offered them by the manufacturers.

The apparatus used for testing the explosives may be roughly classified:—

1. *Projection Machines.*—Usually small guns or mortars, using a small charge to project a comparatively heavy ball, weight, or lever. See Fig. 1. The distance the projectile is thrown is measured, or its momentum is otherwise determined, and the

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result is compared with that obtained from other explosives. The earliest powder gauge known to the author was of this type, and was described by Furttenbach, in 1626. More modern mechanisms of the same general character are used to this day. The Quinan gauge illustrated in Fig. No. 2, is very largely used both in this country and abroad by manufacturers of dynamite to test their own product.

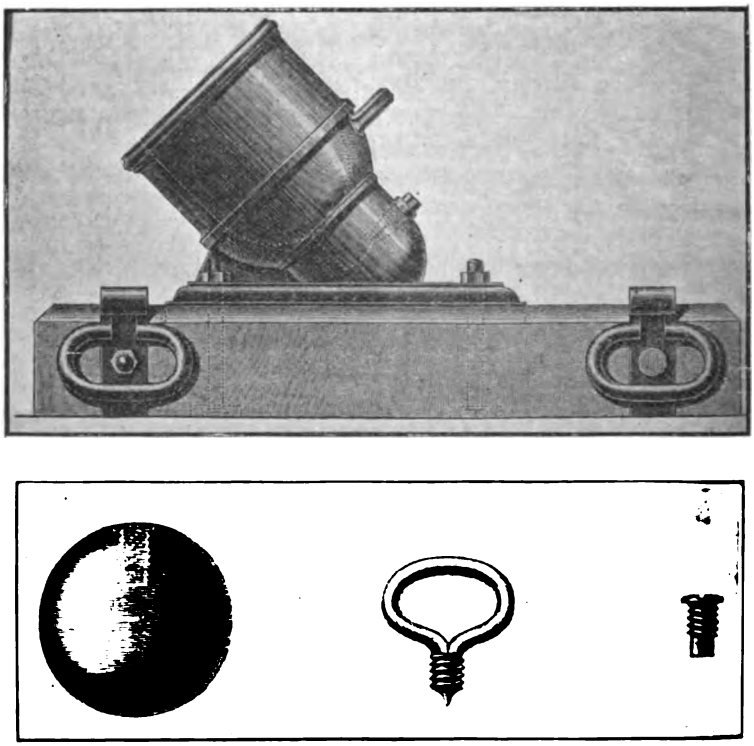

FIG. 1. Mortar for Testing Explosives.

2. *Recoil Apparatus.*—This is practically a reversal of the first type. The gun itself is mounted on a swinging arm, spring, or float, and its recoil is measured with different charges of powders, but under conditions otherwise identical. See Fig. 3.

3. *Velocity Apparatus.*—Usually applied to standard guns or cannon and so arranged that the velocity of the projectile is measured, either in the gun or after leaving it, by chronographs, electrically operated. Apparatus of this type is useful not only

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for testing ammunition but also for studying the laws governing the flight of projectiles, and it has proved of immense value to gunnery experts in connection with the development of modern high range guns.

4. *Penetration Apparatus.*—Usually applied to standard rifles and guns, and so arranged as to cause the projectile to pass through a number of equal sheets of resisting material.

5. *Gas Pressure Recorders.*—Usually in the form of crusher or cutter gauges which can be tapped into the barrel of a gun or cannon to record the maximum pressure developed at the point

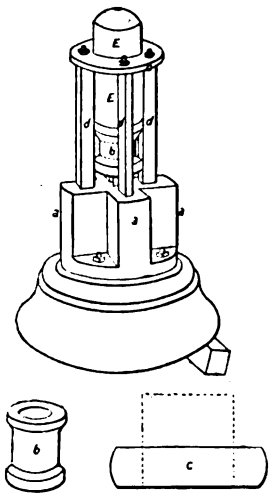

FIG. 2. Quinan Projection Gauge with Crusher Piece.

of insertion. The Rodman cutter gauge (U.S. 1857) and the Noble crusher gauge (Eng. 1860-68) are the best-known pieces of apparatus of this group. The latter is probably the more accurate. See Fig 5.

6. *Closed Explosion Chambers.*—These are provided with crusher or cutter gauges and gas checks to confine the gas produced by explosion and make it possible to determine the maximum pressure developed. The Guttmann gauge, Fig. No. 4, is of this class. In it lead cylinders are driven into the conical ends of the gauge and are thus deformed. The degree of deformation can afterward be measured with extreme accuracy, and from this the pressure can be calculated. The well known Noble pressure gauge (Fig.

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No. 5) is also of this class and uses Noble crusher gauges to record the pressure.

7. *Independent Crusher Gauges.*—Usually hollow closed copper cylinders or small crusher gauges which can be put in a charge and which, if found after the explosion, show by their reduction in size the approximate maximum pressure to which they have been subjected.

8. *Devices for Miniature Blasts.*—Powder is exploded on the surface of or inside of some homogeneous material, such as wood or some ductile metal, and the size of the fracture or cavity

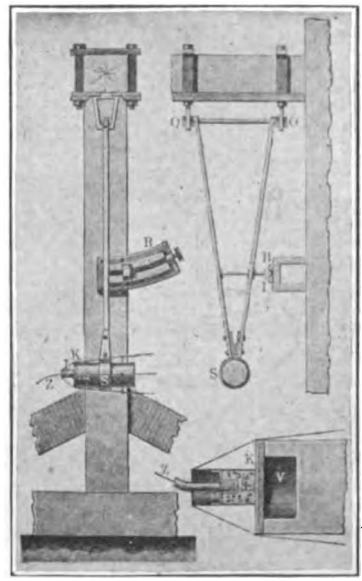

FIG. 3. Ballistic Pendulum.

produced is taken as a gauge of the power of the explosion. Gauges of this class will be discussed at length in a subsequent part of this paper.

9. *Chemical Analysis.*—In addition to tests with the apparatus above mentioned, in which powders are actually exploded, it should be explained that it is now possible to analyze any commercial explosive by standard chemical methods. Any well equipped modern chemical laboratory can make complete and sufficiently accurate analyses to determine the approximate com-

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position of an explosive and its percentage of any such active agent as nitro-glycerine, gun-cotton, etc.

The five classes of apparatus first mentioned are all obviously intended for the investigation of guns and ammunition and need not be discussed at length here, although some of the gauges are most beautiful pieces of apparatus and of great value to ordnance experts. Among these may be named the Chronographic Velocity Recorders of Le Boulenger, Noble, and Mahieu, the Crusher Gauges of Rodman and Noble, and the Manometric Balance of Marcel Deprez.

Explosions in the closed chamber, Group 6, would at first seem likely to give results of use to engineers interested in blasting, but the conditions in a blast are really very different. In the blast, the enclosing substance always yields somewhat and if the

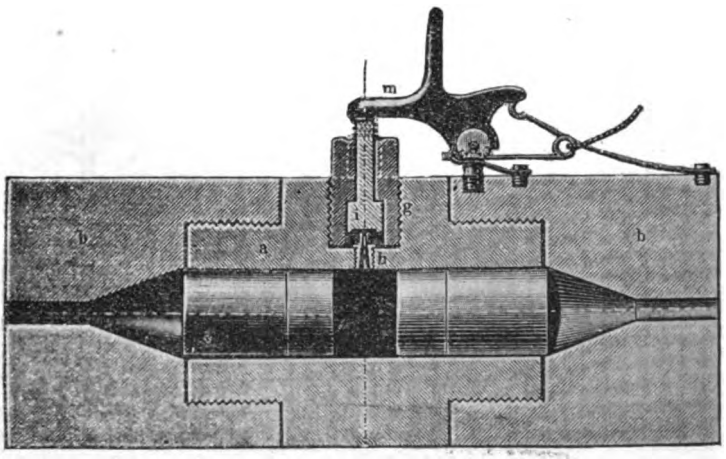

FIG. 4. Guttmann Closed Chamber with Lead Cylinder Crusher Gauges.

quantity and quality of powder are right, the material gives in many if not in all directions. The gases are thus permitted to expand, even while the explosion is still in progress, and although the leakage into fissures in the rock aids in the work of rupture, the temperature and pressure never rise to so high a degree as in a closed vessel.

Similarly, as the main object in blasting is to rupture a brittle substance and only secondarily to eject it, tests with projectiles in guns (class 1) are not properly comparable with blasts, and such a device as the Quinan gauge, although of great value to makers of powder who wish to exactly duplicate standard or

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favourite grades, is certain to give misleading results if used to compare dissimilar powders.

Small crusher cylinders of Class 7 might be used to determine the comparative pressures of different blasts, but the shots would have to be of full size in order to get useful data, and the gauges would be difficult to find in the debris, and when found would often prove to have been damaged by falling rock. The author knows of no attempt to use these gauges except in connection with ordnance, in which case, gauges placed in the gun with the powder can usually be found near the muzzle, and if measured, give indication of the pressure to which they have been subjected.

The eighth class of miniature blasts offers a more hopeful field for experiment. Wood is a variable material, but metal need not be, and for some years the Trauzl cylinders of lead have been considered the best known devices for testing blasting powders.

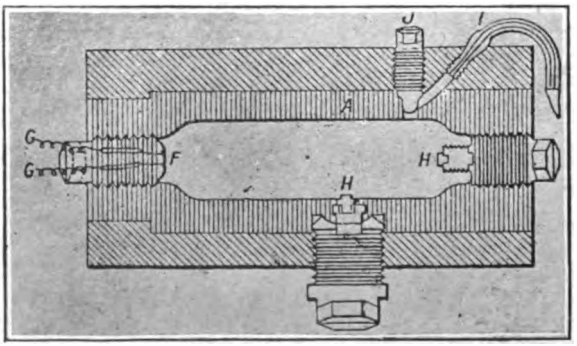

FIG. 5. Noble Closed Chamber Gauge with Noble Crusher Gauge to record Pressure.

As designed by Trauzl and described by such standard authorities as Guttmann, the apparatus is a cylinder of cast lead 200 mm. = 8″ in diameter, 200 mm. high, with a hole 20 mm.=⅘″ in diameter, and 110 mm.= 4⅜″ deep, cored axially from one end to just beyond the centre of the cylinder. Tests are made by placing a weighed quantity, usually 20 grms, of explosive in the cylinder, inserting a standard detonator with fuse, tamping lightly with dry sand, and firing. The hole in which the charge explodes is greatly enlarged, but the proportions of the charge to cylinder are such that the latter is not blown to pieces, and the exact dimensions of the cavity can easily be measured by filling it with water from a graduated vessel. The correction for the force of the detonator can be made by firing a second

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but identical cap alone in a second cylinder and thus the actual power of the powder can be determined by something very similar to a genuine blast.

The most serious fault of the Trauzl test is that the proportions are not those of an ordinary blast, the hole is too short, the fuse is disproportionately large, and the tamping is very ineffective. As a result a very considerable part of the force of the explosion is wasted, and as this loss is greater for slow than for quick powders, the test is unfair to powders which required substantial tamping. Fig. 6 shows standard cylinders before and after a series of tests with different powders.

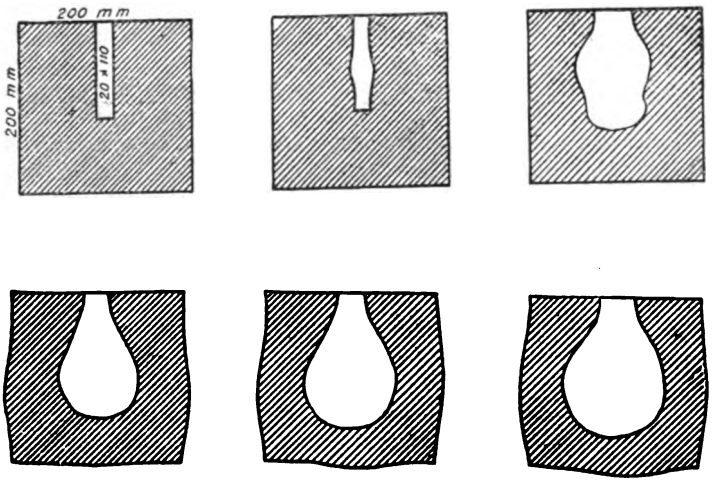

FIG. 6. Standard Trauzl Cylinders.

A few months ago the author had occasion to compare a number of powders, and being convinced that the proportions of the Trauzl cylinder could be changed with advantage, he calculated from theoretical considerations the shape of a lead cylinder in which shots could be fired without undue loss of force through the charging hole. As these cylinders are quite costly, and as each one can be used but once, it was undesirable to make them longer than necessary, yet it was equally important to make them long enough to hold a reasonable amount of tamping and thus to confine the gases until their work was accomplished.

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After a number of experiments, cylinders of 125 mm.=5″ in diameter, and 200 mm.=8″ in height, were decided upon and the bore hole was made 12 mm.=15/32″ in diameter and 135 mm.=5½″ in depth.

As Trauzl cylinders of cast lead have often proved uneven in quality and even leak gas occasionally, arrangements were made to have these new cylinders manufactured in a lead pipe machine, from which the mandril had been removed and a solid cylinder of compressed lead just over 5″ diameter, and many feet in length, was made on special order by the James Robertson Co., of Montreal. This cylinder was then cut into lengths and bored. Subsequent tests proved it to be of perfect homogeneity throughout. Charges of various sizes were used, but 8 grms. was found most satisfactory for high explosives. As the use of a fuse with the Trauzl cylinders seemed always to lessen the efficiency of the tamping, experiments were made with detonators fired by electricity and the small wires leading to these caps were found to interfere scarcely at all with the tamping of dry sharp sand which was run in on top of the charge and shaken down as compactly as possible. As the bore hole was much shorter even in these tests than in practical blasts, this sand tamping was further compressed by placing a lead weight of about 100 pounds on top of it. The cylinders when fired were, in all cases, placed upon an iron anvil weighing half a ton.

A large number of tests were made in these cylinders and the results were most satisfactory. Duplicates, which with ordinary Trauzl cylinders seldom agree to within many per cent., were found with the new cylinders to agree remarkably well. Differences of over one per cent. were very rare, and in most instances the checks were so exact as to be practically identical.

The half-tone cuts 7 to 14, show a series of these cylinders, and it can easily be seen that the conditions of the explosions in them must have been much nearer those of an ordinary blast than in the typical Trauzl cylinders figured above.

The tests above described are still far from being identical in character with standard blasting operations. Lead yields slowly to rupture, and even in the most extreme cases figured the cylinders did not absolutely fly to pieces, whereas blasts in rock, if effective at all, always rupture the material and afford the gas an almost free means of escape. The author believes, however, that tests made in cylinders proportioned as those he has described, will prove to be more fairly comparable with actual blasts than tests made in any other apparatus at present available. Probably the cylinders still give somewhat high results for quick powders, such as dynamite, as compared with slow powders, such

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as common blasting gun powder, but this difficulty can no doubt be largely corrected by further changes in dimensions and by increasing the weight used to confine the tamping.

The most important thing remaining to be done, however, is to compare tests in the cylinders with the results of actual blasting operations on a large scale, and the real purpose of this paper is to interest practicing engineers in the matter, in the hope that they will keep careful records of the results obtained by the use of different makes and grades of powder, and will provide the author with samples of the powder used, so that he in turn may make tests in lead cylinders. By co-operation of this sort between field engineers and experimenters who are able to do accurate laboratory work, it is probable that some definite comparable relation can be proved between practical blasting in different classes of rock and under different conditions of work, and small scale experiments such as have been described.

The author trusts that more than one of his readers will be sufficiently interested to co-operate with him, and he will have great pleasure in making tests and publishing the results of tests on any powders for which sufficiently accurate and practical data are furnished. If these joint experiments bring out some consistent relation between laboratory tests and field work on different classes of rock, the engineering profession will benefit greatly, as it will at once become possible to determine in advance the approximate working strength of different powders and to tell which one will be most suitable for any particular work in prospect.

The following table shows the size of the cavities produced in the cylinders figured in Cuts 7 to 14. The cavities were measured by running in water from an accurate burette, and correction has been made for the volume of the original bore hole and for the effect of the cap. Powder No. 1 was so-called 75% dynamite. and No. 2, was so-called 40% dynamite. By analysis these powders gave 74.25% and 37.65% respectively of pure nitro-glycerine; both were from a well-known manufacturer. Powder No. 7 was a standard black blasting powder from a well-known manufacturer. Powders No. 65 and 75 were experimental explosives of fair quality and uniform composition. Powder No. 50 was an experimental explosive which proved extremely variable, owing to some fault in composition or manufacture. No two tests with this powder gave even approximately equal force, and one or two lots failed to explode.

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TABLE OF RESULTS.

Fig. 7.	Bottom	Cylinder,	style	A—	not fired.			
	Top	"	"	"	Cap only.		Enlargement	2 cc.
" 8.	Top	"	"	"	Powder	7*	"	15½ "
	Bottom	"	"	"	"	50	"	58
" 9.	Top	"	"	B	"	50	"	140
	Bottom	"	"	"	"	50	"	37½
" 10.	Top	"	"	"	"	65	"	170
	Bottom	"	"	"	"	65	"	173
" 11.	Top	"	"	"	"	75	"	237
	Bottom	"	"	"	"	75	"	243
" 12.	Top	"	"	"	"	2	"	274
	Bottom	"	"	"	"	2	"	273
" 13.	Top	"	"	"	"	1	"	473
	Bottom	"	"	"	"	1	"	471
" 14.	Experiments with charges of wrong size.							

The Style A cylinders were made lighter than standard for use with weak powders only. The B cylinders were of the dimensions stated in the paper.

Acknowledgment should be made to Guttmann's valuable works on High Explosives for Figures 1 to 4.

*A duplicate not figured gave enlargement of 14½.

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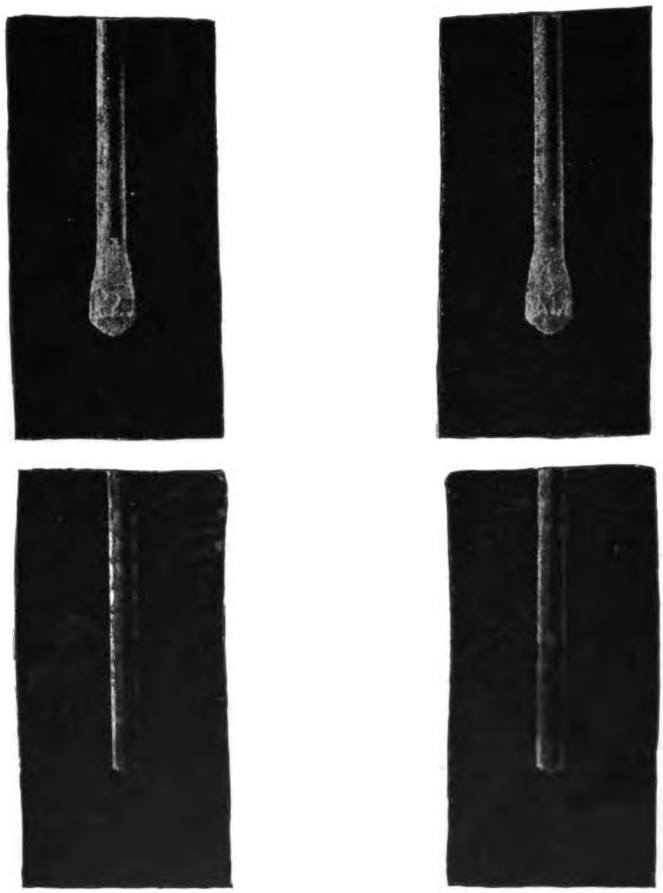

Fig. 7.

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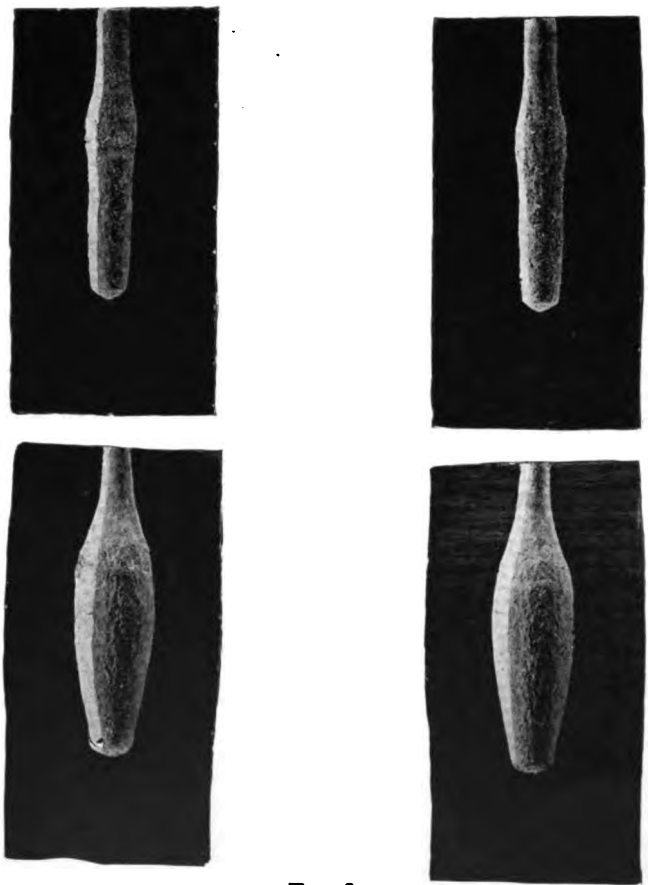

FIG. 8.

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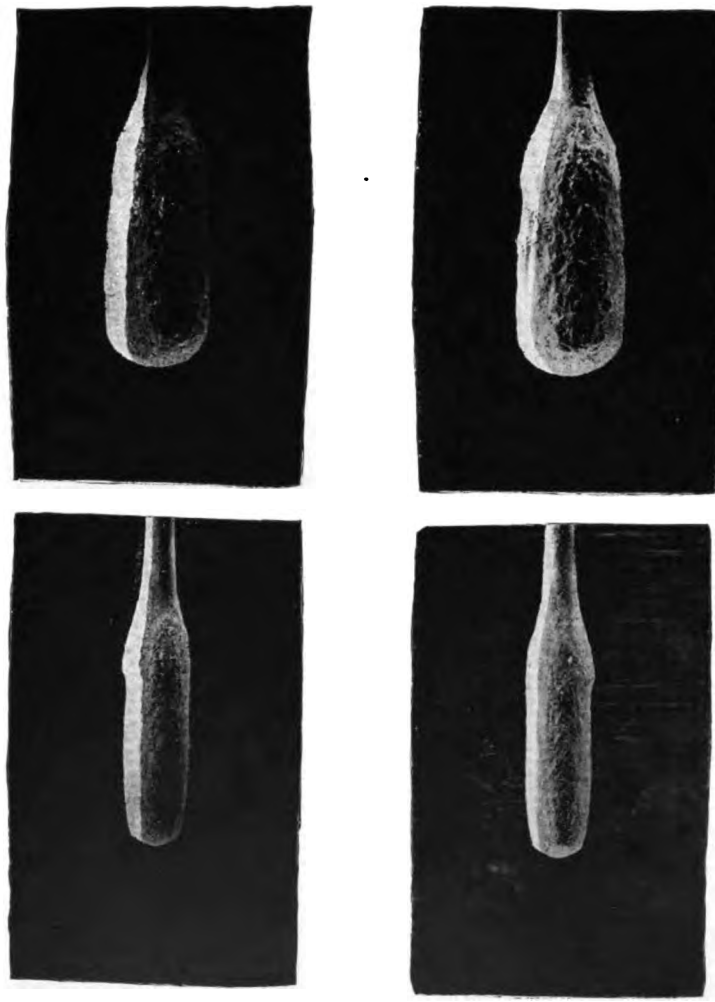

FIG. 9.

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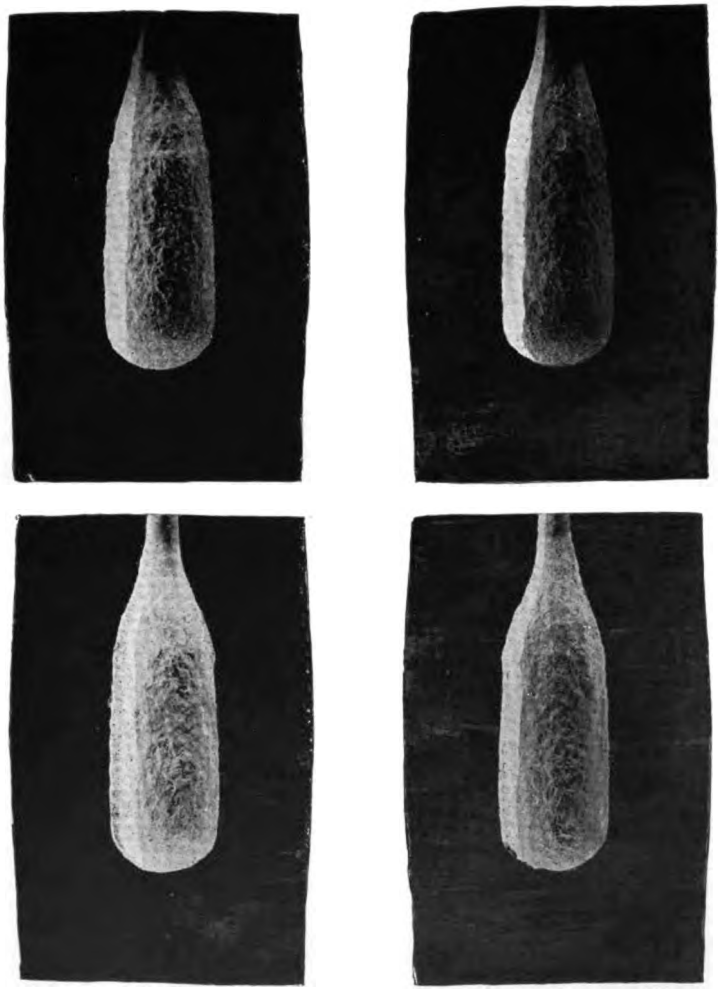

FIG. 10.

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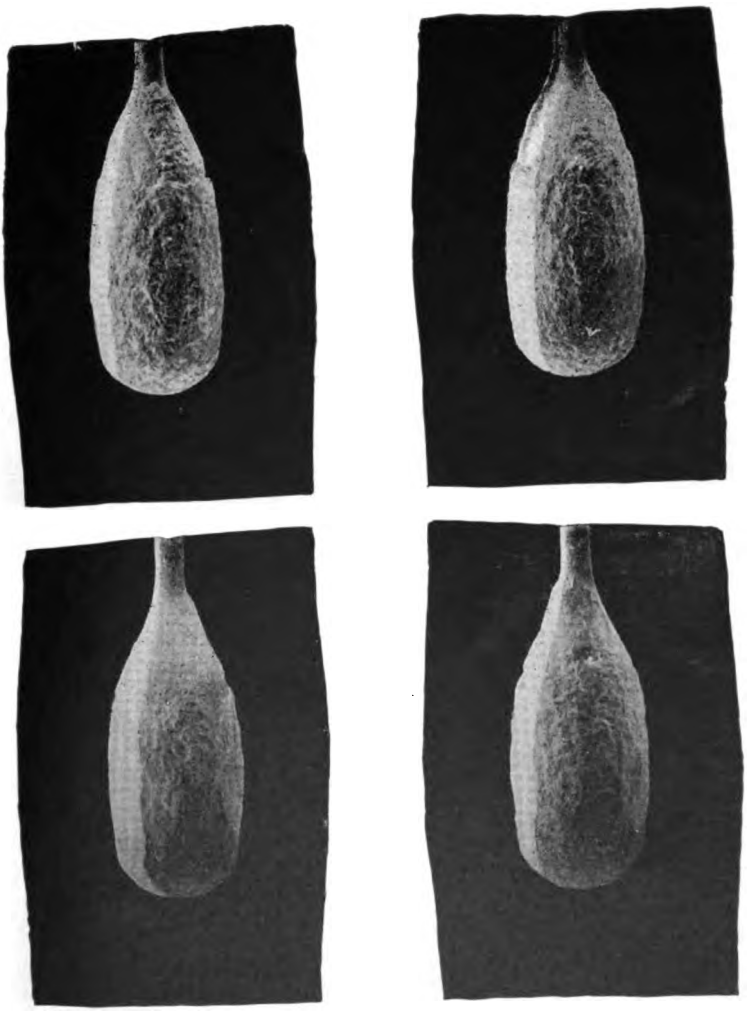

FIG. 11.

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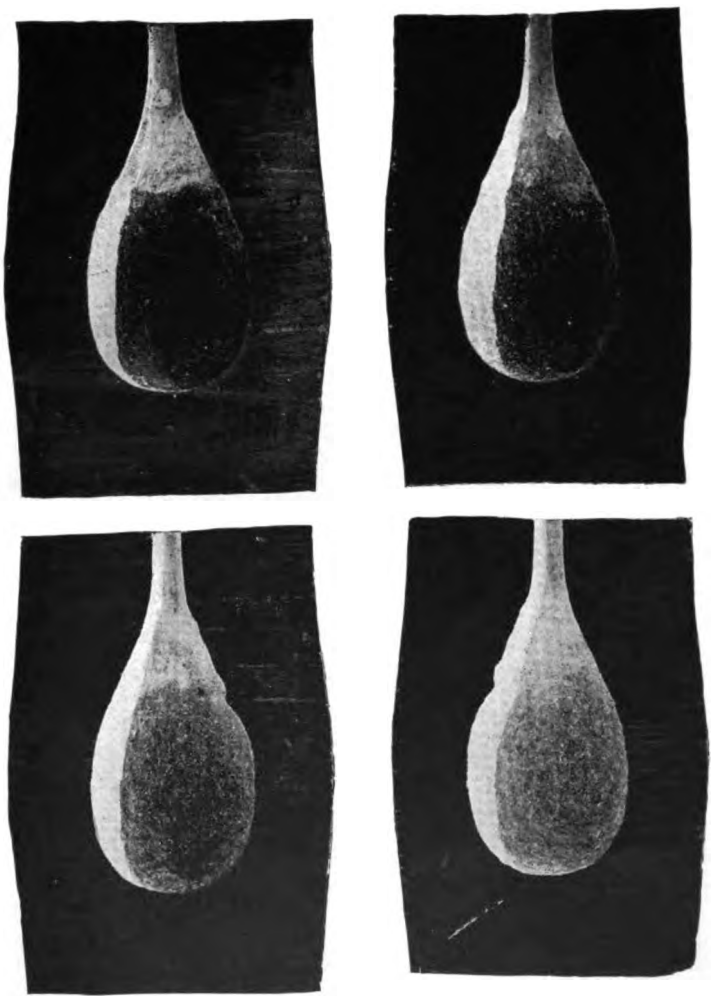

FIG. 12.

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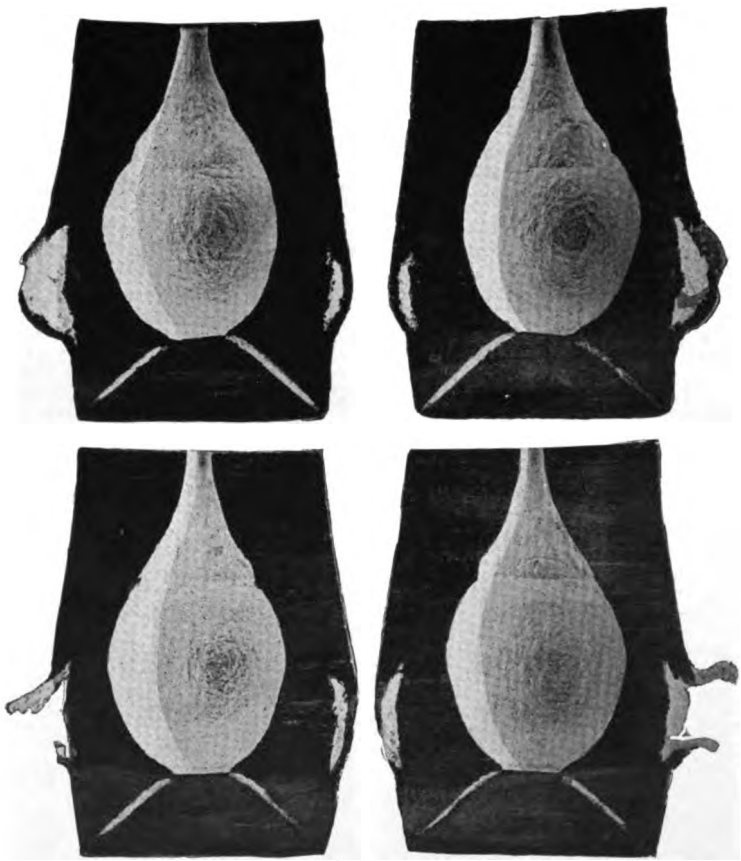

FIG. 18.

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FIG. 14.

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PAPER No. 234.

NOTES ON SOME RECENT EXPERIMENTS ON THE MAGNETIC CONCENTRATION OF IRON SANDS FROM THE LOWER ST. LAWRENCE.

By JOHN F. ROBERTSON, M.Sc., S. Can. Soc. C. E.

In attempting to use the iron sands from the lower St. Lawrence in a blast furnace, three difficulties are met with:—

First, the low percentage of iron on account of the dilution of iron bearing minerals with ordinary sand;

Second, the presence of an amount of titanium much greater than that usually considered permissible in an iron ore;

Third, the fineness of the material.

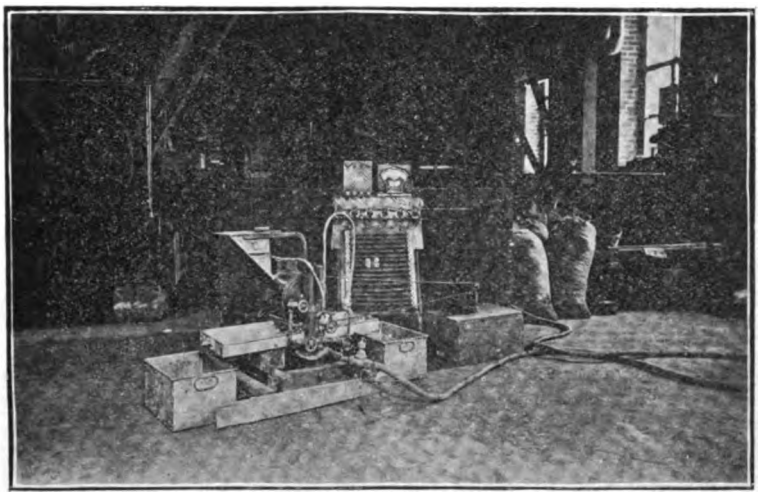

FIG. 1. View of Apparatus.

The third difficulty can be overcome by briquetting and may be left to the metallurgist. This note deals only with attempts to cheaply overcome the first and second difficulties.

The apparatus used in the experiments described below is of special design based on the Heberli drum separator. It consists of a thin hollow brass cylinder about eight inches in diameter and six inches long, revolving loose on a hollow axle through which wires are passed to a set of eight electro magnets arranged radially around the axle, and together filling one-half of the drum. The pole pieces just clear the inside of the brass cylinder.

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Each has a width of ⅝ to 1¼ inches as desired, perpendicular to the axis, and a length of about six inches parallel to it. Each magnet is wound with fifty-five turns of insulated wire, and the wires are led out through the hollow axle to a connection board so arranged that the magnets can be connected in series, or

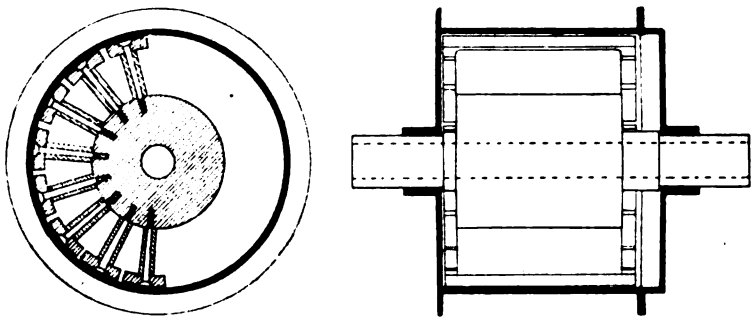

FIG. 2.

Sectional Elevations of Separator.

parallel, and each can be given either north or south polarity. In the experiments described below, the magnets were all in series, with alternate polarity thus: N-S-N-S-N-S. The magnets do not revolve with the cylinder, but may be set to cover any 180 degrees of its circumference desired. The sand is fed to the machine from an adjustable hopper which can be placed in different positions so that the feed can be run in at the top or at any part of the side of the revolving cylinder. Fig. 1 shows a photograph of the whole machine and Fig 2 two sectional elevations of the cylinder.

The advantage of having the magnets of alternate polarity is that the little grains of iron are turned end for end in passing each magnet. As there are eight magnets, the grains of iron are reversed six or seven times, and in trying to arrange themselves to suit the magnetism of the various poles they liberate the grains of sand which might otherwise be entangled in a bunch of grains of iron and thus be carried over into the finished product.

The apparatus was designed to be run either dry or wet and the drum can be rotated in either direction and at a great variety of speeds.

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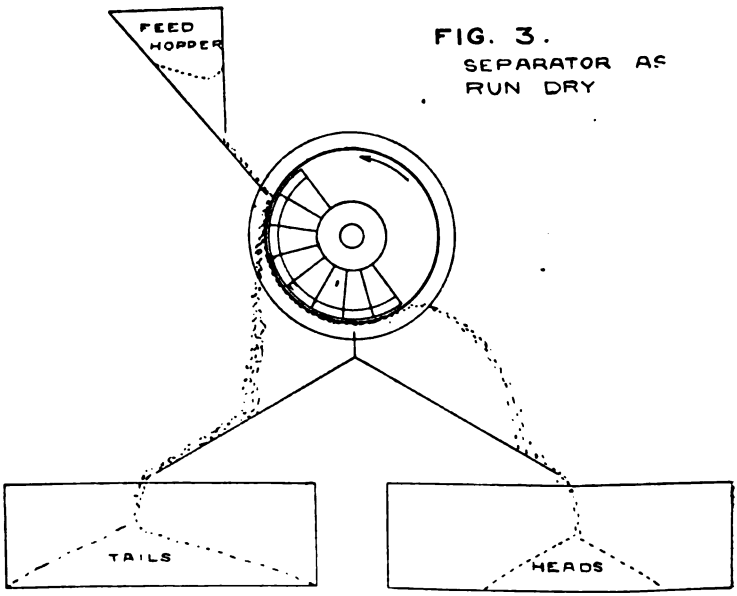

FIG. 3.
SEPARATOR AS RUN DRY

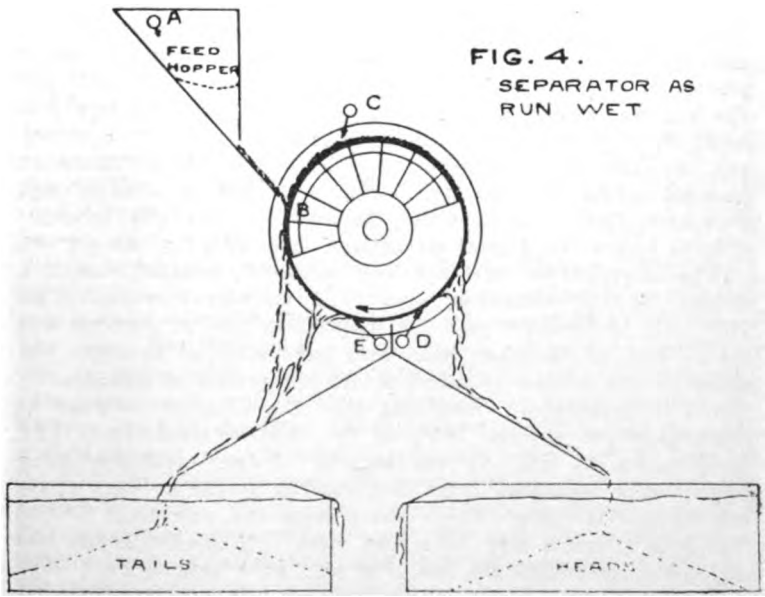

FIG. 4.
SEPARATOR AS RUN WET

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In concentrating dry sands, the machine is run as in Fig. 3, the sand being fed near the top of the revolving cylinder. The non-magnetic material is collected directly under the edge of the cylinder, while the iron, pulled radially by the magnets and moved by the cylinder, passes under the latter and falls off on the other side.

When working with wet sand, the cylinder is rotated in the opposite direction, and the sand fed against the side about half way down. The sand, with some water from the jet A (Fig. 4), reaches the cylinder at B. That part of the cylinder is moving upwards, and the friction of the magnetic material as pulled by the magnets is great enough to carry it with the cylinder against the stream of water from the jet C. The non-magnetic minerals not being attracted, are washed down and away. D and E are two water jets to clean the cylinder from any materials which tend to adhere beyond the proper points for discharge.

It was found that the co-efficient of friction of magnetite on brass is so low that the grains tended to accumulate in rows in front of each pole piece. This difficulty was overcome by placing a few strips of electric tape across the drum parallel to the axis. Covering the drum with canvas was also tried, but while this gave good results in dry concentration, it carried too much non-magnetic stuff when run wet.

The magnetic field utilized in the separator is the stray field. As first designed, the gap between the pole pieces was made quite small, with the result that a large current was required to produce a sufficient strength of stray field outside the cylinder. The gap was then widened, giving better results. It is now proposed to further increase the air gap between the pole pieces, and enclose the whole working side of the apparatus in an external shield or armature. This will cause a stronger and more even field to pass through the drum, and will make it possible to secure the present strength of field with far less current.

The only dry run that has been completely assayed was on a sample of sand containing about 57% metallic iron and 16.2% TiO_2. It is probable that the major part of the titanium was in the form of ilmenite. Some may have occurred as rutile, and some no doubt was contained in minute grains of ilmenite enclosed in magnetite. Assuming that the titanium occurred as ilmenite (Fe Ti O_3) the 16.2% of TiO_2 had combined with it 16.2 x 56/80=11.3% of iron, so the amount of iron capable of being magnetically separated from the titanium would be only 57.0—11.3=45.7%. If rutile (TiO_2) was present the percentage of iron free from titanium may have been more. If much titanium was enclosed in magnetite the free iron may have been less.

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As preliminary work, several field strengths were tried, the weakest used gave practically no concentrates, while the strongest took out nearly all the titaniferous material as well as the magnetite. As magnetite has a much higher magnetic permeability than ilmenite, there should be some strength of field at which the heads product obtained contains almost all the magnetite and still very little ilmenite. Unfortunately grains of ilmenite cannot be distinguished by the eye from grains of magnetite and assays for titanium in the heads and for iron in the tails should have been made to show what were the limiting amperages for successful concentration. In the test in question, this was impracticable and a current of seven amperes was used.

The result from 52 lbs. of sand was 22 lbs. of heads assaying 70.46% of metallic iron and 1.91% of TiO_2 and 30 lbs. of tails assaying 45.30% of metallic iron and 23.30% of TiO_2. This works out to a recovery in the heads of 65% of the total free iron, the heads carrying less than 1/16 of the titanium. A considerably better recovery than this could have been obtained with a slightly higher amperage and no harm done to the product as iron ore having 2.5% of TiO_2 or under is not objected to by blast furnace people.

A screen analysis of 43¼ lbs. of tails from a somewhat similar dry run showed:

(1) Remaining on an 80 mesh sieve.. .. .. .. 9¾ lbs.
(2) Remaining on a 100 mesh sieve.. .. .. .. 27¾ lbs.
(3) Passing through a 100 mesh sieve.. .. .. 5¾ lbs.

Assays of these sizes showed:

	Fe%	SiO_2%	TiO_2 and Al_2O_3%
Over 80 mesh.....	35	15.0	35
80 to 100 mesh.....	42	4.5	35
Under 100 mesh.....	60	1.5	15

The capacity of the machine dry is about 300 lbs. per hour. Its resistance as used is 3 ohms, so the magnets with seven amperes passing required about 150 watts or 1/5 H.P. It takes less than 1/5 H.P. to drive the cylinder, so the total consumption of power is less than one-half H.P. A large machine designed for economy of power could easily do equally good work with one-half or one-third of the current and power per unit weight of sand, viz., from 100 to 150 watt hours per 300 lbs. At 10 cents per killowatt hour, this would amount to 7 to 10 cents per ton of sand. The capacity can probably be further increased by running any but very rich sands very fast so as to make a large amount of poor heads, and then cleaning these heads by re-running them.

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Run wet, the machine will probably duplicate the work it does dry, but the adjustments need more careful watching and the capacity is lower. Six wet runs on sands from Seven Islands gave heads containing 1.10, 2.36, 2.30, 1.48, 1.48, and 1.67% of TiO_2. Preliminary runs on each ore and numerous assays are necessary for the determination of the adjustments required. A wet run for the exhibit of the Quebec Government at the Liege Exhibition, which had to be done without assays or sufficient preliminary work, gave concentrates carrying 7.13% of TiO_2. This sand was practically identical with that used in the six wet runs mentioned above, all of which gave very low titanium in the heads. The assays made after the test was completed, are as follows:—

Heads	Metallic Iron	64.31%
	TiO_2	7.13%
Tails	Metallic Iron	44.95%
	TiO_2	20.17%

The weights were:

Heads	27 lbs. 12 oz.
Middles (not exhibited)	3 lbs. 10 oz.
Tails	27 lbs. 11 oz.

61% of the free iron was got into the heads with about 1/5 of the titanium. The sand was the same as that used in the dry run previously described, and is practically identical with that which gave such excellent results when preliminary assays were made.

The capacity of the separator wet is about 100 lbs. per hour. About 0.02 cu. ft. of water per minute is required to reduce the damp sand to a pulp, and about 0.10 cu. feet per minute to wash the tails from the heads. Sometimes water is used for cleaning the heads and tails from the bottom of the cylinder and sometimes not, The water could easily be pumped back and used over and over. The total power used in the present small machine when running wet costs on an average about 50 cents per ton of sand, but on a large machine this could certainly be cut down to one half or one quarter that amount. The separator either wet or dry is usually run at 87 revolutions per minute. The amperages used range from 3 to 11, 5 and 7 being the commonest.

The machine used in the above tests was designed by Dr. J. B. Porter, Professor of Mining Engineering, and built in the shop of the Mining Department of McGill University. The work detailed was all done under his advice and general direction, but great credit is due Mr. R. A. Chambers, a former student, for tests which he carried out on the Seven Islands sand. The

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author is responsible for the more recent work, and thanks are due Mr. J. Obalski, the Mining Engineer of the Province of Quebec, for material. The chemical analyses were nearly all made by Mr. M. L. Hersey, Provincial Analyst, by authority of Mr. Obalski. The main part of the sand was furnished by Mr. William Robertson, of Montreal, but the Seven Islands sand came from Mr. Ganong, of Quebec. The wet and dry tests last made were carried out at the suggestion of Mr. Obalski and samples of all products were included in the Canadian Exhibit at Liege this year.

On the conclusion of the paper the author exhibited a set of samples of the sand sent to Liege, as follows:—

1: Original sand.
2: Heads of dry concentration.
3: Tails dry concentration.
4: Heads of wet concentration.
5: Middles of wet concentration.
6: Tails of wet concentration.

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DISCUSSION.

Dr. Porter

Dr. Porter remarked that the problem of the magnetic concentration of St. Lawrence iron sand had been a source of interest for a great many years, and the results of Mr. Robertson's experiments would be of interest to all who read his paper.

Regarding these last tests for the Quebec Government, which, as Mr. Robertson had said, were made without sufficient analysis, the need of making careful analysis if accurate results were required was fully appreciated, but the Quebec Government did not make their final arrangements until the time was so short that chemical work could not be done. Mr. Robertson had to guess what would be about the right percentage of current and then sent the sand off to Belgium. Very much better work could have been done had there been more time, and the fault was not from lack of knowledge, but from circumstances. Mr. Robertson had given details of current, etc., which would be of value to anyone studying this subject. All must bear in mind that work with this experimental machine would be more expensive than with an actual commercial machine. The machine was designed for various kinds of work. If they were to design another especially for titaniferous sands, it could be made to work far more economically. The Federal Government had arranged to have a large amount of the magnetic sands collected and arrangements would probably be made to have them tested and smelted. Both Government and private individuals were interested in the matter.

The point brought out in the tests, with a machine which was not economical, was that they had succeeded in getting a comparatively cheap method of separating the iron from the titanium. This was purely an experimental machine and had different adjustments for different experiments, but no adjustment for economy of current.

One means of cheapening the results and getting more effective magnetism would be to enclose the whole machine in an external armature. By referring to Figure 2, all could see that the pole pieces were inside the drum and anyone acquainted with the laws of magnetism would see that only a very small fraction of the field induced by these magnets was utilized. By changing the drum, and especially by using an external armature, it would be possible to get a much greater number of the lines of force to come out through the drum, and, therefore, to be of use.

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Mr. G. H. Dawson referred to Figure 4, and asked the reason why the magnets were continued so far around the drum. The magnets took the material around to almost the last quarter and it seemed that an unnecessary amount of power was used. Mr. Dawson

Mr. Robertson explained that an unnecessary amount of power was certainly used. However, the machine was built as an experiment and with a commercial machine probably two-thirds of the power could be saved. Mr. Robertson

In his early experiments he had failed to sufficiently separate the titanium from the iron and the important point now was that at last they had a machine which would differentiate between the two, and that fairly good economical results had been obtained. The object of the University was to prove that it was possible to separate these two and it was left to commercial people to work out the other details.

Mr. W. A. Duff said that he understood they were unable to get all of the titanium out by this process and that there was enough left in to be objectionable. Mr. Duff

Dr. Porter replied that this question had been taken up with blast furnace people, who informed him that it was the general practice to look upon 2% of titanium as harmless and that it was only seriously objectionable when it rose to 4% or 5%. He did not think it was possible to get all the titanium out, as the minerals did not occur in the free state but in the form of an intimate mixture of mgnetite and ilmenite, and as it had been proved possible to separate down to a point where blast furnace people could not find fault, he considered that the experiment had proved very satisfactory. He had no doubt that they could separate far better, but it would entail greater cost and more loss of iron. Dr. Porter

Mr. Duff said he understood there were ores somewhat similar to the one described containing manganese, and asked if it were possible to concentrate them also. Mr. Duff

Dr. Porter replied that he considered it possible, but he knew of no attempt to make the separation in any Canadian ores, and therefore he could not say definitely what the result would be. Dr. Porter

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PAPER No. 235.

NOTE ON A NEW INSTRUMENT FOR SURVEYING DEEP BORE HOLES.

By J. B. PORTER, D.Sc., M. Can. Soc. C. E.

It is a well-known fact that deep borings are seldom true, and although artesian wells seldom depart very much from the vertical owing to the method of drilling them, yet diamond drill holes and other borings with rotary apparatus very frequently drift very far out of line. So long as the hole is not deep this drifting is not a serious matter, but on holes of say 1,000 feet, the departure from line sometimes exceeds ten per cent. In extreme cases such as certain very deep recent borings near Johannesburg, holes which were intended to be vertical have drifted more than 2,500 feet to one side of their aim.

In view of the great cost of these deep borings it is extremely desirable that the exact location of cores brought to the surface should be determinable, and a number of devices have been introduced within the last few years for the purpose of surveying holes. Most of these devices are comparatively crude and their use involves a great deal of labor.

The apparatus most generally used of late years has been a cylinder of glass, partially filled with hydrofluoric acid. This cylinder, usually less than one inch diameter, is enclosed in a brass case and attached to the end of a string of screwed rods and lowered into the hole to a known depth where it is left for some hours and then withdrawn. The inclination of the hole can easily be read from the glass vessel, as the upper surface of the hydrofluoric acid etches the glass quite distinctly, but the direction of the hole can only be determined by marking the orientation of the top rod while the etching is taking place, marking each joint when the rods are taken apart and finally screwing them together again on the surface in order to compare the orientation marks with the etching on the glass tube. By surveying points at distances of say 300 or even 500 feet, the general course of a bore hole can be determined by the method above described, but the method is laborious and costly and owing to almost unavoidable twisting of the rods the results have seldom proved very satisfactory.

Another method of surveying involves the use of plummets and compasses immersed in a solution of gelatine which slowly hardens after the apparatus has been sent down the hole. This device, although very ingenious, has proved very difficult in use

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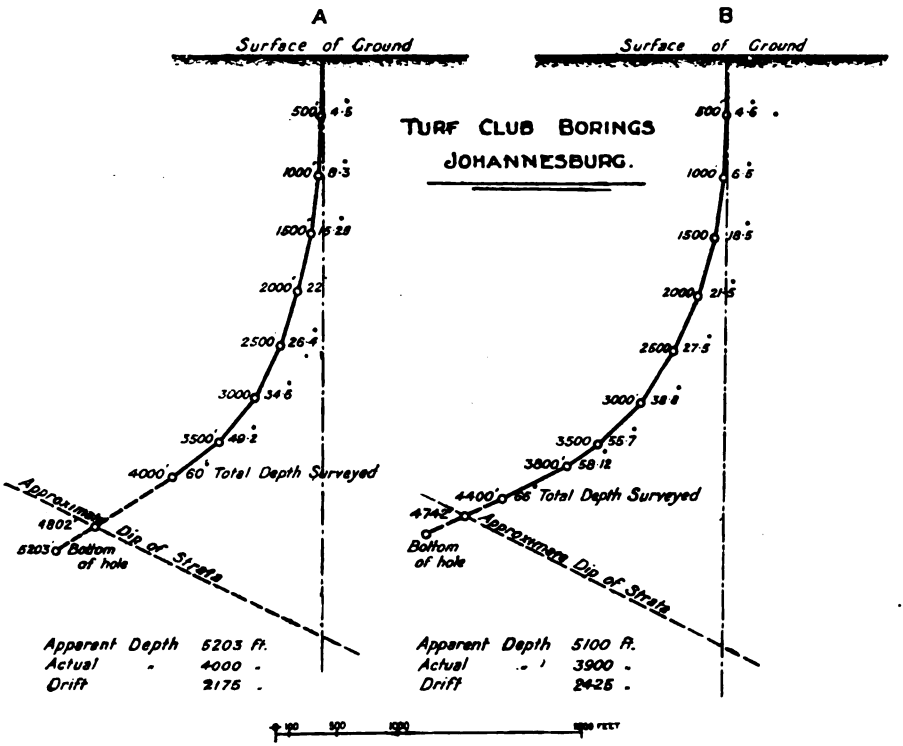
and has not met with much success, especially in deep holes. A very recent form of the apparatus uses paraffine in place of gelatine. The instrument contains an electric resistance and is connected with a dynamo on the surface by double insulated cables. The compass and plummet remain fixed in the solid paraffine while the instrument is lowered to the station in the hole. Current is then sent through the cable and the paraffine melted. The current is then shut off and after sufficient time has elapsed for the paraffine to solidify the instrument is reeled in and its records



read. The apparatus should give accurate results, but the long line of insulated cable is costly and liable to injury. (Marriott—Trans. Inst. Min. and Met., Feb., 1905.)

A few months ago an instrument maker in Johannesburg designed a very ingenious apparatus containing compass, plummet, small cameras, and electric lights, the whole connected with a small adjustable clock so that the light could be turned on for a given period after the apparatus had been lowered into the hole. This apparatus was described by its inventor, Wm. Helme,

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at a meeting of the Institute of Mining Surveyors of the Transvaal on May 27th, 1905. It has since been used in surveying a number of holes and has proven extremely satisfactory.

A prominent mining engineer of the author's acquaintance states that he has had the machine tested by surveying several holes twice and has found the readings to agree so closely in all cases that he scarcely considers it necessary to take check readings unless the first set show some unusual change of direction in the hole. The apparatus, instead of requiring rods, the use of which involves a great expenditure of time and labor, and the use of a derrick and a power hoist, can be lowered on the end of a piece of flexible wire from a large reel and thus several observations per day may be taken by two men.

The writer has not had an opportunity to use the instrument in actual surveying, but has taken a number of observations with it on the surface and has found its records interesting and apparently exact. He therefore feels justified in submitting the following brief description of the instrument taken from the original paper by its inventor:

GENERAL DESCRIPTION.

Briefly described, this instrument is one in which both dip and deviation are recorded by means of photographs of the positions of both a plumb-bob and a magnetic needle at any desired point in a borehole. The photographs are taken by means of two small electric lamps lit by a "time contact."

DETAILED DESCRIPTION.

The instrument comprises a brass cylinder 20 to 30 inches long; both length and diameter are varied to suit the particular requirements. The cylinder is made in two portions, which screw together quite flush shoulder to shoulder. The top and bottom are closed by means of tightly-fitting screwed plugs. To the top plug is attached a brass swivel with an eye piece, by which the instrument is suspended. The swivel is fitted to the plug with ball bearings. The object of this swivel is to prevent the wire, which is used in lowering the instrument, from twisting; also, to minimise risk of the instrument kicking against the sides of the borehole when being lowered or raised. Inside the cylinder, immediately beneath the top plug, is a spring resting on a pad, which keeps firmly in position a small watch or timepiece. Below the watch is a dry battery. Below this again is arranged a tiny electric lamp, and below the lamp is a glass plate, from the centre of which hangs a small plumb bob. Below the plumb-bob is a circular brass plate supported on gimbal bearings, so that it always remains in a horizontal position. On this plate is placed a small disc of sensitised paper. Below this is another electric lamp, and below this again is a compass, which is also supported on gimbal bearings. On the dial plate of the compass is placed another disc of sensitised paper; each disc is pierced by a pin-prick in the centre, and another on one side, and both discs are fixed in exactly the same relative position, one above the other, when in the instrument. The whole is kept firmly in position from below by another spring placed under the little cup holding the magnetic needle, and resting on the bottom screwed plug. When the hand

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of the watch is passing the 12 o'clock point on the dial, it makes contact for about 15 seconds with a small projecting spring made of copper foil, which is connected with one line from the battery. The hand of the watch is connected with the other line ; and so, when in contact with the spring, the circuit is completed ; both electric lamps are lighted ; and photographs are taken of the positions of the plumb-bob and the magnetic needle. It is only necessary to set the watch so that the hand will only pass the 12 o'clock point after sufficient time has elapsed to allow for the instrument being lowered to the required depth, and also to allow for the plumb-bob and magnetic needle having come to rest. In practice, it is usual to take readings at, say, every 200 feet to 300 feet, and two readings should invariably be taken in each instance. When once the photographs have been obtained, the rest of the work is easy ; for, the height of the point of suspension of the plumb-bob above the centre of the disc being known, and the distance of the lower end of the plumb-bob from the centre of the disc having been obtained by accurately measuring the distance between the centre of the photograph of the plumb-bob and the centre of the disc, the angle of dip can be calculated. The direction is also easily obtained by placing the two discs in the same relative positions which they occupied while in the instrument, which can at once be done by means of the two pin-pricks on each. The direction of the line joining the centre with the image of the plumb-bob on the one disc will then (unless it happens to fall in the magnetic meridian) make an angle with the photograph of the magnetic needle on the other disc, and from this angle the magnetic direction of the path of the borehole at that particular point is determined. In surveying a borehole, say 4 000 feet in length, two sets of readings should first be obtained at regular intervals, which should not exceed 250 feet in length. When these have been obtained, the dip and deviation must be calculated for each point, and then sufficient data are available to plot, in plan and section, the true path taken by the borehole. (Proc. Institute of Mine Surveyors, Transvaal, May 27, 1905.)

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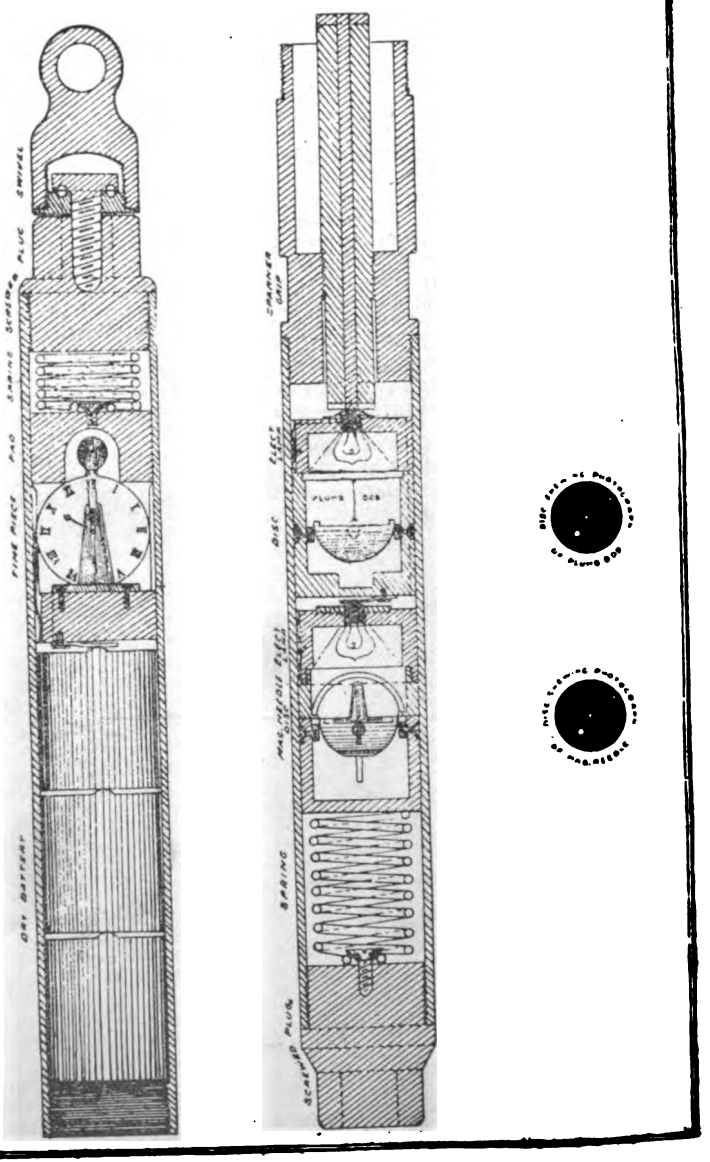
DIAGRAM OF INSTRUMENT



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DISCUSSION.

Prof. McLeod having been asked by the Chairman to give his opinion on the different instruments spoken of, and especially the Helme instrument, said that short of sending a surveyor down a hole he thought the machine was about as complete as could be devised and that it was well calculated to overcome the objections which existed in regard to these surveys. While he had no acquaintance with this class of survey, except from books, he thought in the older method, which depended on the action of hydrofluoric acid on glass, some of the apparatus had been provided with compasses released and then locked by means of a clock-work, which overcame the difficulties mentioned in the paper. Prof. McLeod

Dr. Porter said he knew of this method, but he believed it had never proved very accurate. It was not now used to any extent. He had omitted it and several other methods, for lack of time, and had only mentioned in this paper the more commonly-used devices. Dr. Porter

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GENERAL SECTION.

President—PHELPS JOHNSON.
Vice-President—C. H. RUST.

A meeting of the General Section was held on Thursday, December 14th, 1905, Mr. Phelps Johnson in the chair. The following three papers were read:

PAPER No. 236.

THE GRAND RIVER, ONTARIO PENINSULA:

Effect of Deforestation and Swamp Drainage.

By W. H. BREITHAUPT, M.Can.Soc.C.E.

The peninsula of South-Western Ontario is remarkable for the great bodies of fresh water surrounding it. Taking as north-easterly limit the shortest line between Georgian Bay and Lake Ontario the area of the peninsula is 16,500 sq. miles. The area of the abutting bodies of water, Lake Huron, Lake Erie, and part of Lake Ontario, is 33,900 sq. miles, while adjoining Lake Huron on the west and north-west are Lake Michigan, 2[illegible],000 sq. miles, and Lake Superior, 32,000 sq. miles.

In topography the Peninsula presents what may be called a table land, comprising parts of the counties of Grey, Wellington, and Dufferin (see map, Plate 1,) from which the surface slopes in every direction, abruptly to the north, where the fall is over 1,100 feet in a little more than twenty miles, more gradually towards the west and still more so towards the south-west and south, to the almost level rim of surrounding water, the difference in level between Georgian Bay and the inlet of the Niagara River, i.e., between Lake Huron and Lake Erie, being only about nine feet. In general the surface is rolling. A broad, flat area extends for the greater part from the outlet of Lake Huron along the southerly limit of the peninsula almost to Lake Ontario. A peculiar feature is the Niagara escarpment, an abrupt rise of 200 to 300 feet defining the difference in level between Lake Erie and

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Lake Ontario, and extending along the south shore of Lake Ontario at a distance of from five to ten miles to Hamilton, where it is near the head of Burlington Bay. Thence it stretches to the north and is well defined for a long distance. To the east of what has been called the table land a broad ridge forms the watershed between Georgian Bay and Lake Ontario, sloping down to the level of Lake Simcoe, which is 140 feet above Georgian Bay and 475 feet above Lake Ontario.

Westerly winds are largely preponderant. Graphic evidence of this is afforded on the exposed islands of Georgian Bay, where the wind has almost a clear sweep for 500 miles, by the scrub pine with their well marked slant and their branches mostly on one side of the trunk. The origin of most of the precipitation is herewith indicated. A large part, especially in the south-easterly part of the Peninsula is, however, also due to east winds over Lake Ontario.

Originally the Peninsula was covered with an almost continuous heavy forest of pine and hardwood, interspersed with swamps. In 1901 the woodland area had been reduced to 14.9% of the whole, and since then it has become still less. A large decrease of woodland was noted from 1897 to 1901. There are a few comparatively small forest reserves in Ontario, but none in the Peninsula.

What climatic change has been caused by deforestation is not definitely known. Variations in temperature seem to have become much greater and more abrupt, and transition between the seasons of the year also more abrupt. The forest cover kept the ground moist after rainfall and retarded melting of the snow. Precipitation records have been kept at various points on the lakes for over sixty years. In Toronto the records date from 1840, for which year the record is 29.57 in. rainfall as against 30.4 in. in 1904. The average total precipitation, dividing snowfall by 10 to reduce to water, for sixty years is 33.0 in., with minimum 24.37 in. in 1874, and maximum 48.49 in. in 1878. For the past ten years the average is 31.1 in. There is to be said that rainfall and snowfall observations are at best only approximate. There is a personal equation of the observer, and results have been found to vary materially with the height of the instrument above the ground, other conditions being alike. In the interior of the Peninsula records have been only recent, for about the last twenty-five years, but fairly well distributed. From a table compiled for the years 1883 to 1888 it appears that the greatest precipitation is near the height of the north-west slope, over 40 in., other areas showing mostly 35 to 40 in., and 30 to 35 in. In passing it may be said that this is very favorably above the minimum of 20 in. accepted as necessary for agricultural or pastoral purposes.

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It is clear that precipitation in the Peninsula is not materially affected by deforestation, but is due more to the permanent conditions already outlined. The run-off is, however, very directly affected. The forest cover not only checks evaporation and snow melting but renders the surface permeable so that the water finds its way more readily into the ground to appear elsewhere in the form of springs, and by drawing up and exhaling moisture beneficially affects the atmosphere. Large swamps are natural reservoirs, like great sponges, and are extremely valuable in giving regularity to flow of streams.

The drainage area of the Grand River, as shown in shaded outline (Plate 18), comprises nearly the whole of the counties of Wellington, Waterloo, and Brant, and parts of Dufferin, Halton, Oxford, Wentworth, Norfolk, and Haldimand, a total of 2,600 sq. miles, approximately one-sixth the area, and essentially the central part, of the Peninsula. In its original condition, about up to the year 1800, this whole area was densely wooded or covered with swamp. Some little clearing had been done before that date. From 1800 settlement extended as far as Waterloo County, which by 1820 was mostly taken up. From about 1850 on, settlement extended farther up, but the headwaters of the river in the townships of East and West Luther, Amaranth, Melancthon, and Proton remained practically intact until 1870. The township of Luther, now East and West Luther, as recently as 1871 is described as nearly wholly consisting of impenetrable swamp. The adjoining townships were largely swamp and partly hardwood forest. In the following years drainage of these townships, aided by special provincial legislation and provision of funds, became rapid, as did also the general clearing off of forests.

Up to about the year 1860 the flow of the river was fairly regular, with a good body of water throughout the summer and no great floods as a rule in the spring, except locally where the water might be held back by the formation of ice gorges. The spring freshets were in April or beginning of May, and only exceptionally as early as March. A record kept in Galt beginning with 1858 gives the spring freshets at that point as in March for the four years 1858, 1856, 1860, and 1861 (these years from other records appear to have been very low in snowfall) after which until 1877 they were almost all in April. After 1877 the floods were mostly in March and twice at the end of February.

The minimum summer flow seems to have decreased more particularly since about 1875, coincident with the drainage and clearing of the head townships. From fairly definite evidence at points in Waterloo Township the decrease in the past fifteen years appears to be fully 40% of the minimum in 1890. At Galt (total

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drainage 1,325 sq. miles), and farther down the river the decrease appears not to have been so much. The Speed River empties into the Grand above Galt and the Nith at Paris. (Total drainage 2,020 sq. miles.) The drainage areas of these tributaries have not changed so much in recent years.

The proportion of woodland in the drainage area in 1901 was, by townships, as follows:—

Melancthon	16.2	Wilmott	10.2
Arthur	6.8	Waterloo	9.8
West Luther	7.2	Puslinch	6.9
East Luther	5.3	Blandford	12.4
Amaranth	1.9	Blenheim	8.5
East Garafraxa	6.8	North Dumfries	12.
Maryborough	14.3	South Dumfries	5.4
Peel	14.8	Beverly	11.8
Pilkington	6.5	West Garafraxa	1.4
Nichol	15.1	Burford	11.9
Eramosa	10.7	Oakland	17.3
Erin	5.8	Brantford	2.7
Mornington	10.8	Onondaga	9.
Wellesley	15.4	Townsend	12.8
Woolwich	13.7	Tuscarora	not given
Guelph	7.6	Oneida	11.1
Nassagaweya	21.1	Cayuga	24.4
North East Hope	10.4		

For the whole of the drainage area the percentage of woodland is 9.85.

The main source area of the Grand River may be considered as extending to Elora, above Pilkington Township, with a surface of about 425 sq. miles. The snowfall throughout this section is very great. At Fergus one snowfall year is recorded as 135 in., and a number of years are over 100 in. Formerly the forests and swamps retained the snow and let it off gradually. The country from the north of Melancthon to almost the south line of Luther Townships, an extensive plain, is now of hard surface, largely, though not mostly, in grazing land which can be traversed across country independently of roads in almost any direction. A few warm days in February or March start the run-off with a rush, and it takes but a short time for the accumulation of snow to disappear.

For comparison it will be of interest to note the forestation in some of the oldest and most thickly populated countries of Europe. A recent tabulation, 1902, gives the following percentage of forest to total area:—

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Germany	26%
France	18%
Belgium	17%
Hungary	28%
Austria	32%
Spain	17%
Italy	14%

Could the forestation of the Grand River basin be increased to 20% or more there would be no question of great benefit in regulation of flow. The Provincial Forestry Reports class a large part of land as waste. The total in the Grand River drainage area from the 1901 report is 12.3%, the percentage being larger in the upper townships. Waste lands are given as including swamp and marsh. These are by no means waste when their river regulation value is considered, and for this purpose a large increase of swamp and marsh area would be welcome. There are also large areas of cleared non-arable land, and these present special opportunities for reforestation. In the United States reforestation in various parts of the country has become well established. In Massachusetts, the Boston Metropolitan Water Board alone reforests about 200 acres per annum.

When it is considered that the valley of the Grand River is already well populated, will in a short time have three large cities, Berlin, Galt, and Brantford on the river, and is and will continue to be, one of the foremost manufacturing districts in the Dominion, forethought and provision in the way of establishing conditions to benefit the climate and regulate excesses of the river must be held to be well worth while.

The available water power of the river and its improvement by regulation of flow is a feature of great importance. The total fall from Dundalk, with elevation 1,710 ft., to the mouth of the river is nearly 1,140 ft, Elevations are successively as follows:—

Grand Valley	1,510 ft.
Elora	1,250 ft.
Breslau	961 ft.
Galt	847 ft.
Paris	731 ft.
Brantford	641 ft.
Lake Erie	572.3 ft.

In many places there is a very considerable fall in a short distance. In Elora there is a single drop of over 40 feet, where the river enters a limestone gorge. The water power is made use of at a number of places along the river. Its value is greatly impaired by the extreme low water continuing for about two months in the year.

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FIG. 1

FIG. 2.

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The flow regulation of the river by means of large storage basins is for the present hardly practicable from an economical view point, and will not here be further considered.

The cross-section (Plate 19) taken three miles above Breslau, Waterloo Township, is a typical one for a large part of the river. The low water discharge at this point, as measured in September this year, is 82 cubic ft. per second. The spring flood discharge is approximately 10,500 cubic ft. per second, and has been considerably more. The maximum continues for a short time only, a few days at most. A heavy rain raises the water level very quickly, and has in recent years given a rise of as much as 4 ft. over night. At Brantford the spring flood in 1900 was 16 ft. above low water level. At Galt the minimum flow appears to be about 60% more than at the section given, this being due to the Speed River. Former spring high water and summer low water are shown approximately on the section. The photograph, Figure 1, taken near the section (Plate 19) shows recent high and low water levels, high water being about a foot above the bare place on the tree at the edge of the bank where ice has cut away the bark. Figure 2, near the same place, shows a small elm 8½ in. in diameter immediately above the ice-scarred part of the trunk. High water rises about 6 ft. on this tree. Its age would be about 30 years, indicating the probable period of ice floe encroachment on the ground at its base.

In conclusion it is to be stated that definite observations in the drainage basin are few. Precipitation records have been kept since 1881 only at Guelph at the Ontario Agricultural College, and these are much the most reliable; and at Brantford, Galt, Conestogo, Elora, and Fergus, for periods of from five to ten years. There are no data on run-off, except roughly general ones.

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DISCUSSION.

Mr. Breithaupt

Mr. Breithaupt stated that a great deal of interest was being taken in a possible remedy for this condition of lack of forests, and the Dominion Forestry Association had been interested in the matter. It would carry a great deal of weight if the Canadian Society of Civil Engineers would represent to the Legislature of the Province of Ontario the necessity of some remedy for these conditions.

The farmers were not encouraged to leave their wood standing, as they had to pay high taxes for wooded lands, which returned nothing on their investment, except, perhaps, a little cordwood. If something were done in the way of lowering these taxes, it would probably be of some benefit. Many other suggestions had been made, and among these, at a meeting in Guelph, it was proposed that waste lands be planted with trees and the cost covered by taxation. At Berlin, the Water Works Engineers did not need to consider any such question, as they obtained their water supply from artesian wells, and at Galt a similar condition of affairs existed. A publication of the United States Geological Survey, in connection with rain-fall and run-off, stated that it was generally found that forests did not change the river flow very much, but equalized it. As a general rule, the relation of run-off to rain-fall was from 40 to 60 per cent., but often less than 40 per cent. of the rain-fall flowed into the streams, the remainder going off in evaporation or being used by plant life.

In answer to a question from Mr. Wm. M. Edwards, the author said that no municipalities, so far as he knew, had taken steps towards establishing record stations of their own for keeping records of rain-fall, etc.

Prof. McLeod

Prof. McLeod said that Mr. Breithaupt's paper recalled to him a very important discussion at the annual meeting of 1903. The Society had made some very good resolutions in regard to the matter of asking the Government to measure the flow-off, and a committee had been appointed for this purpose. There was certainly a large amount of work to be done, and it could only be accomplished by organized effort on the part of the Government. He suggested that Mr. Lea take the necessary steps to induce the Government to assume the charge of this important work, which would be of great value to engineers.

Mr. Lea

Mr. Lea replied that it had been proposed to prepare some kind of memorandum and submit it to the Council, which was to push

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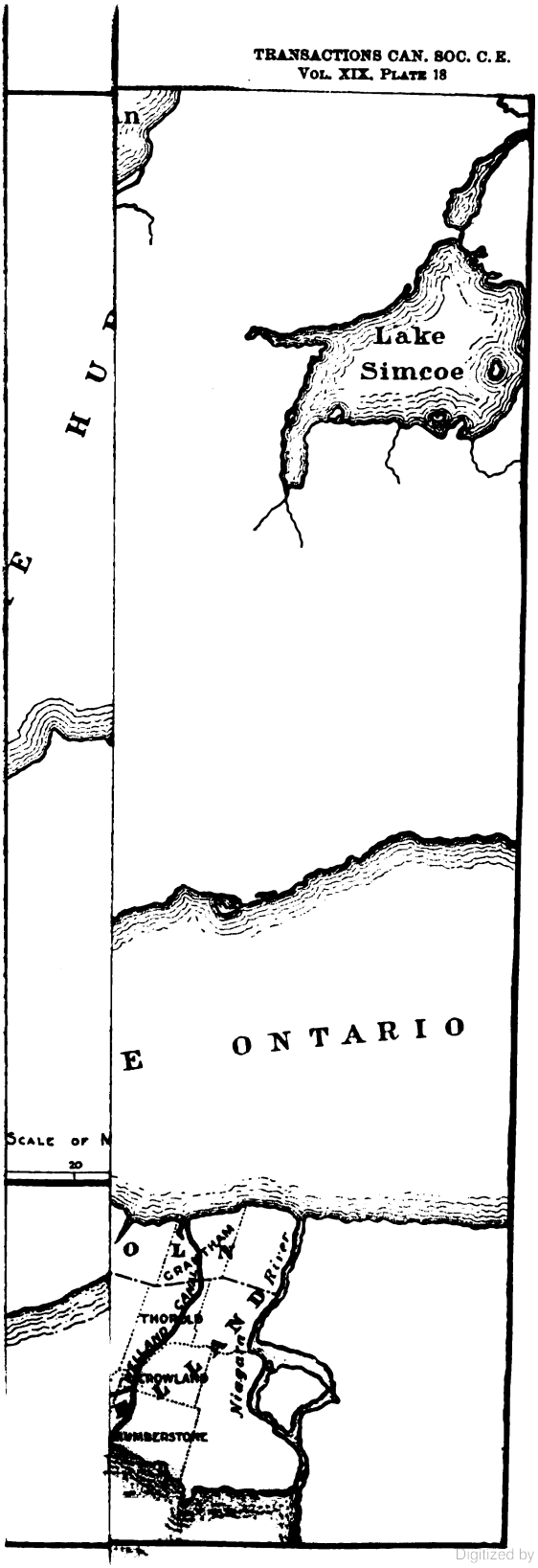

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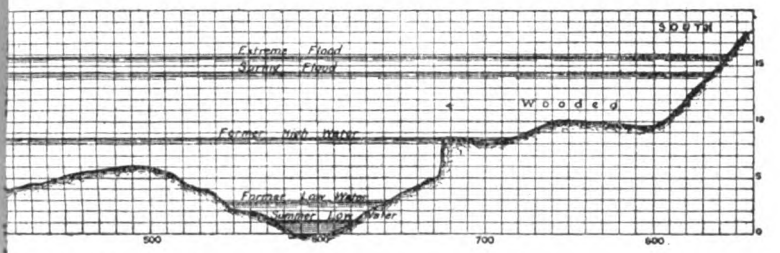

nd River above Breslau

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Mr. B

Prof. I

Mr. Le

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the matter with the Government, in order to have certain streams gauged and measured regularly every day for a long period of years. While this information might not be of much value for some time, it would be eventually, and unless the work was begun soon it would be impossible to obtain the information when it was needed.

Mr. Johnson suggested that the matter be looked into. Nothing could be better than a proper record of certain streams, and it would be well to bring the matter before the Society, and take some course of action in the matter. Mr. Johnson

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PAPER No. 237.

MILITARY ENGINEERING:

Its History and Connection with Civil Engineering.

By Capt. T. E. Naish, R.E., M. Can. Soc. C. E.

Historical:—Military, Civil, and "Ornamental" Engineering.

Man was a fighter before he became an agriculturist or a manufacturer, and so military engineering preceded civil engineering, and has still retained (and always will retain) some of its primitiveness.

Indeed, between military engineering and civil engineering there is historically an intermediate stage which we may call "ornamental engineering,"—to this stage belong the Pyramids, the Colossus at Rhodes, Cleopatra's Needle, and the enormous monoliths in the Phoenician temple wall at Baalbec in Syria. Wherever we notice this stage of "ornamental engineering," we may infer a lengthy period of previous civilization, which will be confirmed by the researches of archaeology.

We know that Egyptian civilization had existed for a long time when the Great Pyramid was built by Cheops, though that event took place nearly 4,000 years B.C., because the art of that same period had long passed the barbaric state, and shows signs of elaboration; and the religion that brought the enormous granite sarcophagi of the underground temple of Serapis hundreds of miles down the Nile, was not that of a primitive people. It would seem that the ancient world had no call for utilitarian engineering, for the energies of the engineer in peace time were only turned to unproductive and monumental works.

Perhaps the earliest civil engineering works now in existence are ancient canals and irrigation works;—we read of a celebrated Chinese engineer named Yü who was engaged in canal building in B C. 2,200, and we know that there were very ancient irrigation works in connection with the Nile and its annual flood.

Probably the oldest military engineering work now extant is the great wall of China; similar to it, but following thousands of years after, are the Roman walls built from sea to sea across the north of England, to keep off the invasions of the Picts and Scots.

The very traces of the greatest military engineering feats of old have from the nature of things disappeared, such as the bridge of boats built by Xerxes across the Hellespont, the damming of the River Euphrates at Babylon to effect an attack of the city along

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the dried river bed, the ignition of the besiegers' ships at Syracuse with burning-glasses by Archimedes and his lifting of the same ships by huge cranes.

The earliest road making was for military purposes,—perhaps the best known (though not the most ancient) example of which is the Roman roads in Great Britain; the peculiarity of these roads is, that they run often in a perfectly straight direction for many miles, ignoring hills. They are still in many cases in use, and retain their ancient names, such as Watling Street, Fosse Way, etc.

As in the case of the Chinese and Egyptian civilizations, the first example of civil engineering on the part of the Romans took the form of hydraulic works and aqueducts, and are in many places still in existence.

But one might almost say that civil engineering is the growth of the last century;—up to that time the word "engineer" meant military engineer, and when Shakespeare said

" 'Tis sport to see the engineer, hoist by his own petard,"

it was not necessary for him to qualify the word.

The engineer in Shakespeare's time was engineer and artillerist in one,—he managed the engines of war, which then used gunpowder instead of the more primitive propelling forces of the catapult, and he blew in the gates of a town or castle with a petard instead of using the more primitive battering ram. In those days the word "artillery" was applied to the art of the archer, as will be seen in the authorized translation (date about A.D. 1600) of the Bible (story of David and Jonathan).

Likenesses and Contrasts in the Various Branches of Civil and Military Engineering.

In the enormous development of civil engineering during the nineteenth century, it was the steam engine that set the avalanche moving, gaining volume at every foot of its onward progress.

There has been no corresponding development of military engineering, but it has been rendered increasingly difficult to become a good military engineer. The military engineer must scan the whole field of hydraulic, railway, mining, electric, mechanical and sanitary engineering, and pick out from each branch what will be useful to him. He cannot afford to neglect any, and must be dependent on the specialist in each for the advancement of his own science, for though he may very often become a specialist himself, yet he must never neglect a knowledge of the other branches.

It is not, however, a case of being "master of all trades," for he need only know what of each trade is capable of military ap-

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plication. To take an example:—Development in bridge building has scarcely affected the military art at all, which still remains primitive,—military bridges are almost entirely built of timber, rope and nails. It is true that the military engineer may be called upon to repair steel bridges or stone arches as in the South African war, but he does this primarily by erecting a temporary timber structure (completed in a few hours) and then proceeds more leisurely to a permanent repair if the proximity of the enemy permits. Boat bridging is almost entirely a military art, and a branch of the Royal Engineers called the "Pontoon troop" has this as its special occupation. Again, the destruction of bridges is a problem seldom faced except by the military engineer.

Of course, the functions of the civil and military engineer often overlap; principally in survey, in railway engineering, and in telegraphy.

For many reasons it may be convenient to carry out surveys by a military organization, as in the Ordnance Survey of the British Isles, the Survey of India, etc., and in some cases it may be absolutely necessary (as on a hostile frontier); but the methods and instruments employed by military engineers are almost exactly the same as those of civil engineers. It is convenient to build many railways on or close to the India frontier under military direction, and it was absolutely necessary so to build the railway from Cairo to Khartoum by which the Soudan was re-conquered; and here again the methods of military and civil engineer are the same.

As far as mechanical engineering is concerned, the military engineer takes a civil invention, such as the steam engine, oil engine, bicycle, motor car, and adapts it for military purposes; similarly with the lathe, shaping machine, drilling machine, etc., when applied to the manufacture of big guns and other military material.

The principles of sanitation are the same for the military engineer as for the civil engineer, but they have respectively to apply them to widely varying conditions, as will be seen by comparing the problems of water supply and disposal of refuse for an army of 30,000 men spread out for a variable period along, of a front of (say) 15 miles, and that for a similar number of inhabitants occupying permanent dwellings in a city.

Telegraph and telephone work (including wireless telegraphy) are almost exactly similar in their military and civil developments, civil inventions being applicable almost without adaptation to military requirements; but these sciences come in warfare under a large head which may be called "signalling," and include the conveying of signals to a distance by semaphore, waving flags or flashing lights.

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Electric lighting has been applied to harbour defence, search lights or fixed beams taking about 25 H. P. to run them, and also to siege operations.

Fortress Warfare From a Civil Engineering Point of View.

To turn from generalities to an actual example of modern warfare, let us imagine a staff of civil engineers, experts in all the branches, placed under the command of the general who is besieging Port Arthur, to give him the benefit of their advice. How can the fortress be reduced? First, the water supply may be cut off, and the railway rendered useless to the besiegers.

The throwing of explosives from a distance is now the work of the artillery, and the preparation of the sites for the guns requires more military knowledge than particularly scientific engineering.

But how to approach the chain of forts that protects the fortress? Can the engineers devise any means to protect the attacking troops from the hail of lead than mows them down in swathes like grass, even at a distance of 600 yards,—can shields be devised light enough to carry and yet impenetrable to bullets? Can any means be devised to cut those terrible wire entanglements? or to divert the electricity with which they are charged?

The fortress must be reduced in six months;—can tunnelling equipment be procured that can drive a tunnel 2,000 yards in that time and so enable a charge of explosive to be placed under a fort? Can any modern methods of excavating be employed? or are the pick and shovel to be the only tools for earthworks?

We can see how essential telegraphs and telephones would be to the conduct of the siege, and how ballooning would have a field of its own; but for the most part the refinements of civil engineering would be useless,—none the less there would be ample scope for the common sense, readiness of resource, and energy which every successful civil engineer should possess.

Final Broad View of Subject,—the Patriotic Standpoint.

Taking a final view of the subject discussed, and from the broadest point of view, we find a close connection between civil and military engineering. Civil engineering has been defined as harnessing the great forces of nature for the service of man, and *military engineering may be defined as harnessing those great forces for the service of one's country.*

Looking at it from this point of view, can the building of the Siberian railroad be called distinctively either a military or civil operation? And can the building of the Canadian Pacific Railroad be considered entirely a civil operation? No more than a strike,

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when organized labour enlists natural forces on its side against organized capital, can be considered a really peaceful operation.

There are more ways of conquering a nation than by actually shooting its inhabitants;—its food supply (for instance) may be cut off, and this may be done by apparently peaceful operations. In the establishment of the internal communications of Canada free from all warlike interruptions, that might disturb its supply of food, of fuel, and of raw material for manufacturers, are not the civil engineers of Canada doing the work that is most essential for the defence of their native land?

In such works as the new Transcontinental Railway, the Georgian Bay Canal, and railway communication to Hudson Bay, Canadian civil engineers are carrying out nothing less than the peaceful conquest of their own country.

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DISCUSSION.

Mr. H. R. Lordly read some notes he had prepared on this subject, in which he stated that any engineer with good sense, judgment, and patriotism would make a good military engineer, as illustrated in the war between the Northern and Southern States, which was so successfully carried on, much to the astonishment of military experts of other countries. Mr. Lordly

A new corps had been organized recently in Canada, which would be of interest to the members of the Society, viz., the Intelligence Corps, directed by two members of the Society of Royal Engineers, the membership of which was made up largely from the Canadian Society of Civil Engineers. The chief work of this corps was to provide military engineers in time of war. There was great competition for admittance into this Corps of Guides, and no one was admitted unless he could be of use and could pass the required examinations. The Government, however, sought and would continue to seek the services of members of this Society.

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PAPER No. 238.

AN ASPHALT PLANT FOR WALKS AND CROSSINGS IN SMALL CITIES.

By H. B. R. CRAIG, A. M. Can. Soc. C. E.

In dealing with this subject, the writer proposes to describe an asphalt plant operated by the city of Kingston for the past twelve years.

This plant occupies a space of half an acre in one of the corporation yards, but at the same time, should much asphalt work be done in any district of the city far away from the yard, the entire plant may be advantageously moved to a convenient place in that locality. A covered shed, 30 by 20 feet, serves as a protection to the plant proper, and the remaining space is used for storing the stock of asphalt, tar, and fuel, and for tarring the broken stone.

The plant consists of an asphalt boiler of 40 gallons capacity, a sand-heater with a surface of 100 square feet, and a mixing-board of about the same size. The sand-heater is simply a sheet-iron plate, half an inch thick, resting on four brick walls two feet high and one foot wide, enclosing an oven. The fuel is fed to the oven through a hole in one of the walls. The initial cost of the plant was $105.00.

In operating this plant the daily pay roll amounts to $12.74, and itemized is as follows:—

2 Labourers—Boiling Asphalt, heating sand, and mixing, @ $1.50	$3.00
1 Labourer—Boiling Asphalt, heating sand, and mixing, @ $1.57	1.57
1 Labourer—Preparing the foundation, @ $1.50	1.50
1 Labourer—Preparing the foundation, @ $1.35	1.35
1 Labourer—Laying and finishing the surface mixture, @ $1.57	1.57
1 Labourer—Laying and finishing the surface mixture, @ $1.50	1.50
1 Carter—Carting the mixture to the walk, @ $2.25	2.25
	$12.74

There is no charge made for superintendence, as the foreman of streets attends to that.

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The cost of the various materials is as follows:—

Asphalt	1.57 cents per pound.
Sand	90.0 cents per cubic yard.
Cement	170.0 cents per 350-lb. barrel.
Gravel	75.0 cents per cubic yard.
Tar	1.0 cent per pound.

The daily output of the above force is about 300 square feet of finished crossing or walk.

The following statement shows in detail the cost of laying 15,000 square feet of asphalt crossings during the year 1905:

Material	Cost in cts. per sq. ft.	Labor.	Cost in cts. per sq. ft.
Stone	0.267	Boiling Asphalt and heating sand	1.25
Asphalt	3.690	Carting	1.088
Cement	0.080	Laying and finishing surface	0.917
Fuel	0.110	Preparing foundation	1.020
Hardware	0.015		
Tarred Gravel	0.510		
Sand	0.630		
	5.302		4.275

Total cost per square foot of crossing 9.577 cents.

It will be noticed that the charge for fuel is very small. That is due to the fact that the fuel is obtained from the old plank walks which are torn up when being replaced by new walks. The only charge, therefore, is that of cartage.

The cost of crossings is less than that of walks as the expense of preparing the foundation is a little more with the latter than with the former, and more tarred gravel is required in the case of the walks to give the surface mixture a firm base.

The manner of construction of the asphalt crossings is as follows:—

Surface Mixture.

(*a*) 270 pounds of Acme asphalt are heated to 300 degrees Fahrenheit and kept at that temperature for about two hours, being constantly stirred.

(*b*) 20 bushels of medium coarse sand, screened of all material ½ of an inch and over, are heated to drive off the moisture.

(*c*) The asphalt and sand are then thoroughly mixed by hand on the mixing-board.

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Laying on Macadam Roadways.

A furrow is picked up along the edge of the crossing so as to produce the desired camber and to prevent the wheels of vehicles from cutting into the asphalt. A load or two of tarred gravel in addition to this may be required along the length of the crossing.

The asphalt surface mixture is then laid on the foundation as prepared to a depth of two inches. It is well tamped and pounded along the edges and thoroughly rolled with a heavy two-man roller, the surface of the roller and the pounder being first well oiled so as to prevent the mixture from adhering to them. A thin coating of cement is then sprinkled over the wearing surface and wetted down, about one pound of cement being required for every ten square feet of crossing.

Should the crossing require to be used on the same day or if the work is done in very hot weather, some limestone screenings spread over it and well wetted down will act as a protection.

Asphalt walks are constructed in a similar manner, with the exception of the foundation course. The ground is cleared of all loose material and graded to a firm, even base, cinders well sprinkled and tamped being used to bring the walk to the required elevation. On the cinders is placed a 4-inch layer of tarred gravel. This course is pounded to give a firm, even bearing for the surface mixture, which is then laid as before.

On a heavily travelled street with the roadway abutting the walk, a concrete curb of the usual design is built in place along the outer edge of the walk. Wherever feasible, however, the usual custom is to arch the outside edge of the walk and tamp it well into a small furrow. In this way an almost vertical face may be produced. Limestone screenings may then be placed along this edge for backing. A 1 by 10 inch form properly braced is placed along the inside edge of the walk before construction and is usually left there.

A method sometimes used for the outside face is a 2 by 10 inch form braced by means of 4-inch cedar posts placed every six feet on the walk side of the form and driven one foot into the ground. This is not to be recommended as the posts will eventually be heaved up by the action of the frost, thus destroying the wearing surface, and the form soon rots out.

The life of the asphalt crossings is found to vary from ten to twenty years. This together with such a low initial cost renders them vastly preferable to plank crossings and even to many of the more expensive crossings, such as those built of concrete, brick, or stone. For example there are several crossings built of asphalt in Kingston which have outlasted the surfaces of heavy concrete crossings of the same age and two to three times the initial cost.

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Another point in favor of asphalt for both crossings and walks is its elasticity, which when not too great is very desirable.

Several varieties of asphalt have been tried in this city, such as Trinadad Lake, Kiola, and Acme. The last brand is at present used and the mixture as given is found to be simple and to produce good results.

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DISCUSSION.

Mr. Lordly

Mr. H. R. Lordly recommended that the author of the paper be asked to include in his charges the time for superintendence by the foreman, and also the actual value of the fuel, because, if the old planks were of value to the city for fuel, they should be charged to the plant and the city credited with the amount. By making this alteration, the paper would be of some value as a comparative statement.

Mr. Craig

Mr. Craig agreed that the foreman's time should be charged to the asphalt work. The charge would amount to 0.14 cents per square foot.

Mr. Goldmark

Mr. Henry Goldmark asked about the wearing quality of roadways built of asphalt, as compared with those built entirely of concrete, and said he would like to know if anyone present had had any experience in that line.

The question was why roadways of this class were not more general. He had read that concrete roads were commencing to come into use.

Mr. Craig

Mr. Craig replied that it was generally conceded that cement concrete roadways were inferior to those surfaced with asphalt. He could not name any municipality which had met with success in the operation of pavements of the former kind. The objections to cement concrete roadways were their friability on account of being so hard and unyielding; their extreme slipperiness, especially in wet and frosty weather; and their greater cost, as compared with a sheet asphalt or a bituminous concrete roadway. Cement concrete as a foundation for asphalt block and brick pavements had, however, proved a success.

Mr. Hannaford

Mr. Hannaford added that the concrete crossings in Kingston had not lasted as well as the asphalt. Crossings on Clarence street, at the corner of King and Ontario streets, had been in use for twelve years and the whole surface was chipped off, in some places to a depth of two or three inches. Asphalt crossings under the same conditions and at just as busy places seemed to have lasted much better.

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MEMOIR OF JOSEPH TOMLINSON.

By WILLIAM P. ANDERSON and J. A. L. WADDELL.

There passed away on May 10th, 1905, at the ripe old age of 89, Joseph Tomlinson, at one time Lighthouse Engineer in the Marine Department of Canada, and later Bridge Engineer in the Department of Railways; who, although never a member of the Canadian Society, having retired from active practice of his profession soon after this Society was organized, was yet so well known and esteemed by the older generation of engineers, and did such good work for Canadian engineering, that it is eminently proper and appropriate that some record of his life and work should appear in the transactions of this national society of civil engineers; the more so, because Mr. Tomlinson was of so modest and retiring a disposition that he never sought publicity for himself or his work, and has, consequently, been forgotten by many of our younger members.

He was born in Ruskington, Lincolnshire, on 22nd June 1816, being one of a family of fourteen children of Joseph and Ann (Shearwood) Tomlinson, his father being a land-owner who farmed extensively. As a boy he was considered dull, and disappointed his parents so much that they early removed him from school, where the old-fashioned classical curriculum did not appeal to his mathematical instincts, and apprenticed him to a cabinet-maker at Newark. But, as often happens, they misunderstood his capabilities. Long before he was out of his time, he was acknowledged to be a better workman than his master, and during the seven long years of his apprenticeship, he made opportunities, after the long hours in the workshop, to study mathematics and draughtsmanship, and with the help of a Mechanics' Institute, laid the foundation of those habits of hard work, study and general reading, that he kept up to the day of his death. The thorough training in framing and woodfitting he received under the old system of long apprenticeship undoubtedly stood him in good stead throughout his entire professional career, for he was often called upon to supervise the fieldwork of large constructions. On such occasions there was no detail of the actual construction work that he could not undertake with his own hands—and powerful hands they were, for when in his prime he possessed a wonderful physique. This ability to do, as well as to direct manual and skilled labour was a great advantage, in that it

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gained for him the respect, as his kindly and genial nature gained the esteem, of all his workmen.

During his youth, England was in the throes of the great social revolution that culminated in the Chartist riots, and Mr. Tomlinson knew and listened to the teachings of the great reform leaders, and had impressed on his youthful imagination the duties of self-denial, of work for the betterment of his fellows; in short, of socialism, in the best sense of the word; ideals to which he remained constant through life.

In 1840, when he was 24 years of age, Mr. Tomlinson came to America and settled in New Milford, Conn. Here he found the practice in his own trade so radically different from the thorough methods in which he had been trained that he drifted into other branches of the work, and soon found his vocation in bridge building, through the following incident: On inspecting a railway bridge under construction, he confided to his friend, Rev. Dr. Noah Porter, afterwards President of Yale College, his opinion that a miscalculation had been made regarding its resistance and weight, and when his judgment was justified by the subsequent partial collapse of the bridge, Mr. Tomlinson was employed to repair it, and acting on Dr. Porter's advice, turned his attention to engineering, subsequently designing and building a great many bridges on the Housatonic Railway extension, the Whitehall and Rutland Railway, and the Harlem Railway extension.

The first bridge he ever planned and built, as a contractor, was a bridge at Pittsfield, Conn., in 1844, which is still standing.

He prepared plans for and financed the Whitehall tunnel, after its construction had been attempted and practically abandoned because of the inroads of the quicksand. On the plans of this tunnel, he worked without a single hour's cessation for three days and three nights, and this power of concentration and prolonged work was characteristic of the man.

From 1854 to 1862 Mr. Tomlinson was employed by the New Brunswick Government constructing bridges, and it speaks well for the honesty of his work and materials that after half a century most of these wooden bridges are still standing.

The only bridge he built that fell was a bridge over the River St. John at Grand Falls, N.B. Into this bridge he was induced to incorporate Nova Scotia iron that had not been tested. On the completion of the bridge it was opened with some ceremony, and carried safely a multitude of people and a procession of sleighs, but the next day, under the strain of 30° of frost, it fell when loaded with only a single team. This bridge was rebuilt by Mr. Tomlinson, as a suspension bridge, with tested materials, and is still standing. Although the Government assumed full blame for the catastrophe,

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it is typical of Mr. Tomlinson that he never put in a bill and was never paid for his work on the fallen bridge.

The first bridge he built in New Brunswick was the Hammond River Bridge, still in use. The best known of his New Brunswick bridges is the suspension bridge over the falls in the city of St. John. In later years he was temporarily borrowed from his lighthouse work to put in for the I. C. R. the foundations of the railway bridges over the Miramichi River.

From New Brunswick, Mr. Tomlinson moved to Ohio, in 1862, where he was connected with the Lake Shore and Michigan Southern Railway, and later supervised some important structures for the city of Cleveland, including the building of a large market house.

Mr. Tomlinson was called to Kansas City, Mo., in 1867, by Mr. Octave Chanute, to act as engineer of the superstructure of the Hannibal bridge across the Missouri River, the first permanent bridge to cross that great stream. He designed the superstructure, and after the channel piers had been washed out, was put in charge of the foundations, replaced them from original designs and completed the bridge with perfect success.

When the Honourable Peter Mitchell was organizing the Marine Department after Confederation and wanted an engineer who could undertake the construction of a large number of lighthouses expeditiously and economically, he bethought him of the man whom he had known while in the Provincial Government, and who had served his native Province so successfully as a worker in wood, and invited Mr. Tomlinson to return to Canada, which he did, remaining in charge of lighthouse construction during the growing time between 1870 and 1880; and although his buildings are all cheap wooden structures, they were efficient and were erected with marvelous rapidity and economy, considering the great extent of coast to be covered and the difficulty of access to many of the sites. It was while he held this position of General Superintendent of Lighthouses that the writers of this memoir had the privilege of becoming acquainted with him, by working under him, and are, therefore, in a position to appreciate the great work he did in that office. The Department, when he joined it, was absolutely new and had to absorb and assimilate the heterogeneous practices of a dozen Lighthouse Boards. Designs had to be evolved without previous records for consultation; and the amount of work required could have been accomplished only by a man of first-rate practical ability. Many of Mr. Tomlinson's towers still guard the approaches to the Dominion and are beautiful examples of heavy braced framing. The two octagonal lighthouses on Sable Island, erected in 1873, and the

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tall tower on Greenly Island, may be quoted as examples of his best work.

He greatly improved the illuminating apparatus that he found in use, substituting petroleum for the Colza and seal oils previously used, devising improved burners, verifying each step of his progress by photometric and laboratory tests, and personally instructing the lightkeepers in the proper methods of getting the best results from the apparatus put in their charge.

In 1880, Mr. Tomlinson was transferred to the Department of Railways, to design the wooden truss bridges and trestles for the Government sections of the Canadian Pacific Railway, and got out a set of standard designs, which were used throughout the work.

In 1882 he was sent by the Canadian Government to England, to supervise the manufacture of the metal-work for the long cantilever bridge that was to span the Fraser River on the main line of the Canadian Pacific Railway. Later on he superintended the erection of this noted structure. This was his last considerable engineering work, and in 1885 he accepted superannuation and settled in Cedar Rapids, Iowa, to be near a large farm that he had bought in that neighborhood many years previously, and which is now managed by his eldest son. He remained at Cedar Rapids, with his wife and youngest daughter, until his death, which occurred very suddenly, while he was engaged in his favorite recreation of gardening.

In 1845 Mr. Tomlinson married Miss Anna R. Northrup, of New Milford, Conn., and three daughters were born to the marriage, one of whom is still living. Mrs. Tomlinson died in 1852, and in September, 1853, he married Miss Sarah A. Wyles, of Lincolnshire, England, by whom he had five children, four of whom, with his wife, survive him. One of his sons, Mr. A. T. Tomlinson, is a member of our Society.

Mr. Tomlinson's principal characteristics as an engineer were extreme thoroughness in detail, neatness of execution, great persistency, and absolute honesty. He did personally a great deal of draughting on his various designs, and very few draughtsmen have ever equalled him in neatness of execution and fineness of work.

One of the main reasons for Mr. Tomlinson's great success as an engineer was the love he had for his work. He laboured for the work's sake, and not merely for the compensation received, a fact which was often taken advantage of by those who employed him.

There was nothing to which he looked back with greater satisfaction than to the difficulties in construction he had successfully overcome. He had absolute faith in his own ability, notwithstanding which he was always noted for his extreme modesty. He was

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ever ready to acknowledge merit in others; and had a most decided hatred for everything that tends to give one man an unfair advantage over another.

His principles gave him great influence over his workmen, many of the best of them following him from one job to another; and in every way he endeavoured to benefit them, signing the temperance pledge for the sake of example, establishing reading rooms for them, and continually striving to elevate their minds and improve their material condition.

As a bridge engineer, he was far in advance of his age, and worked out his designs from carefully-calculated strain sheets, when most bridges were being erected by rule of thumb. He retained his mental activity up to the day of his death; and during the last months of his life was engaged in evolving a design for a very long suspension bridge, in connection with which he took out three patents. Despite his great age, the drawings for this bridge were essentially as fine as those he made during the prime of his life, and are now being used as models of draughtsmanship for young engineers.

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Canadian Society of Civil Engineers.

877 DORCHESTER STREET, MONTREAL.

Established Feb. 24, 1887: Incorporated by Dominion Act, June 23rd, 1887.

(50 Vic., Cap. 124.)

CHARTER, BY-LAWS

AND

LIST OF MEMBERS

1905.

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CHARTER

OF

The Canadian Society of Civil Engineers.

(INCORPORATED JUNE 23RD, 1887.)

WHEREAS the persons hereinafter named have, by petition, set forth that it is desirable that they, together with such other persons as may be hereafter associated with them, be incorporated into a society by the name of "The Canadian Society of Civil Engineers," having for its objects and purposes to facilitate the acquirement and interchange of professional knowledge among its members, and more particularly to promote the acquisition of that species of knowledge which has special reference to the profession of civil engineering, and further to encourage investigation in connection with all branches and departments of knowledge connected with the profession; and whereas it is expedient to grant the prayer of the said petitioners; therefore, Her Majesty, by and with the advice and consent of the Senate and House of Commons of Canada, enacts as follows:—

1. Thomas C. Keefer, Ottawa; Casimir S. Gzowski, Toronto; John Kennedy, Montreal; Henry T. Bovey, Montreal; Frederick N. Gisborne, Ottawa; Edmund P. Hannaford, Montreal; William T. Jennings, London; Samuel Keefer, Brockville; Louis Lesage, Montreal; Hugh D. Lumsden, Toronto; Alan Macdougall, Toronto; Henry F. Perley, Ottawa; Hurd Peters, St. John, New Brunswick; Peter A. Peterson, Montreal; Henry S. Poole, Stellarton, Nova Scotia; Henry N. Ruttan, Winnipeg; Collingwood Schreiber, Ottawa; Percival W. St. George, Montreal; and Herbert Wallis, Montreal, and all other persons who may hereafter be associated with them, shall be and they are hereby constituted a body politic and corporate, under the name of "The Canadian Society of Civil Engineers."

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2. The said Society shall have power to acquire and hold all lands and property necessary and required, in order to carry out the objects and purposes for which incorporation is sought, provided that the annual value of the real estate, held at any one time for the actual use of the Society, shall not exceed five thousand dollars; and the said Society shall also have power to sue and be sued, and implead by their corporate name; and to make and pass regulations and by-laws for the direction and management of the said Society, including all rules that may be deemed necessary for the maintenance of the honour and dignity of the profession.

3. The said Society shall be governed by a President, Vice-Presidents and Council, to be constituted in such manner as may be provided by the by-laws hereafter to be made, and the persons named in the first section shall constitute such Council, until such appointments are made.

4. A meeting of the said Council shall be held within six months after the incorporation of the Society, for organization, making by-laws, the election of officers, and the transaction of any other business that may arise.

5. The head office of the Society shall be in the city of Montreal, or in any such other place as may from time to time be determined by a vote of two-thirds of the Members of the Society.

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BY-LAWS

OF

The Canadian Society of Civil Engineers.

Name and Objects.

1. This Society shall be called "The Canadian Society of Civil Engineers." Name of Society.

2. The term "Civil Engineer," as used in this Society, shall mean all who are, or have been, engaged in the designing or constructing of railways, canals, harbours, lighthouses, bridges, roads, river improvements or other hydraulic works, sanitary, electrical, mining, mechanical or military works, or in the study and practice of navigation by water or air, or in the directing of the great sources of power in nature for the use and convenience of man. Definition of Civil Engineers.

3. The objects of this Society shall be (1) to facilitate the acquirement and interchange of professional knowledge among its members, and (2) to encourage original investigation. Objects of Society

Constitution and Membership.

4. The Society shall consist of Honorary Members, Members, Associate Members, Associates and Students. Honorary Members shall not be subject to fees or dues, and shall not be entitled to vote, unless they have previously been Members, in which case they shall retain the right to vote and hold office. Members and Associate Members shall be styled "Voting Members." Associates and Students shall possess all the rights and privileges of Members and Associate Members, except the right to vote or to hold office. Composition of Society.

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Titles of Membership.

5. Any Honorary Member, Member, Associate Member, Associate or Student, having occasion to designate himself as belonging to the Society, shall state the class to which he belongs, according to the following abbreviated forms:—Hon. M. Can. Soc. C.E., M. Can. Soc. C.E., A.M., Can. Soc. C.E., A. Can. Soc. C.E., Stud. Can. Soc. C.E.

Qualification for Election as Members.

Qualification of Honorary Members.

6. Honorary Members shall be distinguished men, eminent in Engineering or kindred sciences.

Qualification of Members.

7. Every candidate for election as Member must be at least thirty years of age, and must have been engaged in some branch of Engineering for at least ten years, which period may include apprenticeship, or pupilage in a qualified Engineer's office, or a term of instruction in some school of Engineering recognized by the Council. The term of ten years will be reduced to eight years in the case of any candidate who has graduated with honours in his Engineering course. In every case the candidate must have had responsible charge of work for at least five years, and this not merely as a skilled workman, but as an Engineer qualified to design and direct Engineering works.

Qualification of Associate Members.

8. Every candidate for election as an Associate Member must have been engaged in some branch of Engineering for at least five years, which period may include apprenticeship or pupilage in a qualified Engineer's office, or a term of instruction in some school of Engineering recognized by the Council. In every case the candidate must have held a position of professional responsibility for at least two years.

Qualification of Associates.

9. Every candidate for election as Associate shall be one who is not a Civil Engineer by profession, but whose pursuits, scientific acquirements or practical experience qualify him to co-operate with Engineers in the advancement of professional knowledge.

Qualification of Students.

10. Every candidate for election as Student must be at least sixteen years of age, and must present a certificate of having successfully passed an examination, equivalent to the final examination of a High School or the matriculation of an Arts or Science course, and must be pursuing a recognized course of instruction in some branch of Engineering, or be receiving a practical training in the profession. He shall not remain in the class of Student more than nine years.

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Manner of Election of Members.

Mode of election of Honorary Members.

11. Honorary Members must be nominated by a unanimous vote of the Council, one month's notice having been given to the members of the said Council of the names of the nominees, and of the meeting at which it is proposed to make the nomination. The election of Honorary Members shall be by vote of the Members of the Society, given in the same manner as in the election of Members. The number of Honorary Members shall not, at any one time, exceed twenty.

Notice of election of Hon. Member.

12. The Secretary shall notify by letter the Honorary Member of his election, and shall request him to notify the Society of his acceptance of the same within six months. Failing such acceptance, his election will be void.

Mode of election and promotion to several classes.

13. Proposals for admission to the Society as Member, Associate Member or Associate (Form A in the Appendix), or for transfer from one class to a higher (Form B in the Appendix), shall contain a statement over the candidate's signature, of his age, residence, and the nature and term of his professional service, also an agreement to conform to the regulations of the Society if elected or promoted. The applicant shall give as references at least five Voting Members, from whom the Council shall obtain satisfactory evidence in writing that they personally know the candidate, and that he is worthy of acceptance or promotion. The proposals for Students shall be signed by the applicant and endorsed by one Voting Member.

Ballot.

14. Election for any class, or for transfer, shall be by vote of the Members taken by letter ballot, according to a form to be prescribed by the Council, and such ballot shall be taken at the first ordinary meeting held after the lapse of at least twenty-five days from the date of mailing the notification. If ten per cent. of the votes cast be negative, the candidate shall be excluded, and in such case no record of the transaction shall be kept. Provided, however, that should the Council require that an examination be passed by any candidate for admission into the Society, or for transfer from one class into another, or should any candidate request to be admitted or transferred by examination, then the Council may admit or transfer the candidate thus, provided he pass such examination as the Council may prescribe.

Notification of election.

15. On the election of a candidate, he shall be immediately notified by the Secretary (Form C in the Appendix). On receipt of

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the notification he must subscribe to the Constitution and By-Laws (in the terms set forth in Form D in the Appendix), and pay to the Treasurer the regular fees (see Articles 18, 19 and 19*a*) before he can be entitled to the privileges of membership. Should he fail to do so within six months from the date of the notification of his election, he shall cease to be a Member. Membership shall date from the day of the election.

Certificates of Membership.

16. All certificates of membership issued to Members are the property of the Society, and must be returned by any Member who has resigned, or whose name has been removed from the roll of membership, within one week of his receipt of notice of such removal or acceptance of resignation.

Expulsion.

Expulsion

17. Upon the request of ten or more Members, that, for causes specified, a Member of the Society should be expelled, the Council shall advise the said Member that his resignation will be accepted. He may, upon demand, receive a copy of the charges against him, and present a written defence. Two months after such action on his part the Council shall finally consider the case, and if resignation has not been tendered, or a satisfactory defence made, will then notify the Member that he will be expelled in one month, unless he elects to appeal from this decision, in which case his appeal shall be voted on by letter ballot.

Neither the Council nor the Members bringing the charge shall vote. If ten per cent. of the votes are for expulsion, the Member shall be expelled, and the Council shall notify the said Member and the Society of the result. In case no appeal is made, the Council shall expel the said Member, and notify him and the Society of his expulsion, and such notification shall in any event be the only notice, public or private, taken of the matter.

Dues.

Definition of resident and non-resident Members.

18. Members, Associate Members, Associates and Students who reside within fifty miles of the headquarters of the Society shall be deemed resident; those who reside beyond the limit of fifty miles shall be deemed non-resident.

Annual fees.

19. Each resident Member shall pay $10.00, and each non-resident Member, $8.00 per annum. Each resident Associate Member shall pay $8.00, and each non-resident Associate Member, $6.00 per annum. Each Associate shall pay $10.00 per annum. Each Student shall pay $2.00 per annum. Student members who are also

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active members of an Engineering or Scientific Society in any University or Engineering school in Canada may, with the approval of the Council, have one dollar of the above fee remitted to them.

19*a*. Associate Members, upon admission to the Society, shall pay a fee of $10.00. Members, upon admission to the Society, shall pay a fee of $20.00. Associate Members, upon transfer to the Class of Member shall pay an additional fee of $10.00. Students upon being transferred to the Class of Associate Member shall pay a fee of $10.00. This By-Law shall not apply to those who become Corporate Members of the Society under the provisions of the Quebec Act.

Resignation.

20. Every person admitted to the Society shall be liable for all dues until he shall have signified to the Secretary, in writing, his desire to withdraw, when, if his dues have been fully paid up, his name will be omitted from the list of membership.

Annual Fees due on Jan 1st.

21. All annual subscriptions shall become due on the first day of January in each year for the year then commencing, but no Member shall be considered in arrears for any year until after the thirty-first day of May of that year. It shall be the duty of the Secretary to notify each Member of the amount due for the ensuing year, at the time of giving notice of the annual meeting.

Interest.

21a. On the first of July of each year, interest amounting to two and one-half per cent. shall be added, and on each succeeding first of January and first of July until the said fees be paid. This interest shall be collectable in the same manner as the Annual fees.

Members in arrears have no vote.

22. No Member or Associate Member whose dues are in arrears shall be allowed to vote. Any person admitted into the Society, who shall refuse to pay any dues, or who shall neglect the same for six months after notice thereof shall have been issued (Form C in the Appendix), may, by a vote of the Council, be struck off from the roll of membership.

Reinstatement on roll of Membership.

23. Any Member who, for non-payment of dues, has been struck off the roll of membership, may again, if the Council approve, join the Society on payment of all arrears, and on payment of such entrance fee as may hereafter be agreed upon.

Change in amount of Annual Fees.

24. The amount of the annual dues to be paid for the support of the Society may be changed from time to time at the Annual General Meeting of the Society, provided that notice of intended action thereon shall have been given to the Members two months

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previously by circular. No alteration in the amount of said fee shall apply to the fiscal year during which it is made, but shall take effect on and after the first day of January next succeeding the date of such alteration. Those who become resident or non-resident by removal of residence shall be subject to the dues of the class to which they belong at the date of the Annual Meeting, as may be shown by the records of the Society, or by written notice to the Secretary.

Compounding of Fees.

25. Any Member may compound his fee and become a Life Member on payment of a sum of $150.00, which is to be invested by the Council, the interest only to be used for current expenses.

Exemption from payment of dues.

26. The Council may, for sufficient cause, exempt from payment of annual dues any Member distinguished in his professional career, who from ill-health, advanced age, or for other good reason assigned does not continue to carry on a lucrative practice, and is unable to pay such dues. The Council may remit the whole or part of any arrears, or accept in lieu thereof desirable additions to the Library and Museum.

Officers.

Officers.

27. The officers of the Society shall consist of a President, three Vice-Presidents, Treasurer, a Secretary; the last three surviving Past Presidents who continue to be Members, who shall be styled Honorary Councillors; and twenty Councillors. Of the twenty Councillors elected, at least eight shall be representative of the four sectional departments of engineering, not less than two for each section having been nominated as such. Of these representatives of sections at least one for each section must be resident at headquarters.

Council.

Composition of Council.

28. There shall be a Council, consisting of the President, Vice-Presidents, Treasurer, Secretary, Honorary Councillors and Councillors, and of this Council five shall constitute a quorum. The Members of Council shall retain their position until their successors have been appointed.

SECTIONS.

28*a* There shall be four sections of engineering in the Society, viz.: Electrical, Mechanical, Mining and General. At its first meeting after the annual meeting, the Council shall name for each section a President and a Vice-President, both of whom shall be members of Council and at least one resident at headquarters, to

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hold office for one year from the first day of June next following. Each section may at its first meeting appoint a member, associate member or student to act as recording secretary at all meetings of the section during the year. The several sections are empowered to extend the privileges of their meetings under such conditions as they may prescribe to engineers not members of the Society, or other persons interested in engineering. The papers read and discussed by each section shall be published in the Society's transactions, if approved by the Committee on papers

MANAGEMENT.

Chairman of Society meetings.

29. The President or, in his absence, one of the Vice-Presidents, or, in their absence, a Member of Council, shall preside at all meetings of the Society. In the event of the absence of the President and of all the Vice-Presidents and Members of Council, the meeting may select any member as Chairman. The Sectional meetings shall be presided over by the President or Vice-President of the Section or in their absence, by a member of the Society.

Duties of Secretary.

30. The Secretary shall keep an accurate record of the transactions of the Society and of the Council. He shall also keep a correct roll of Members' names, with their addresses and dates of their admission. He shall conduct the correspondence of the Society, give notice of all meetings, supervise the printing, and, under the direction of the Council, edit the transactions of the Society.

Duties of Treasurer.

31. The Treasurer shall have charge of the funds of the Society, shall receive all money and pay all accounts and orders approved of by the Council, or by the Finance or Library and House Committee. He shall also deposit and invest the Funds of the Society in its name, and always with the approval of the Council. All accounts exceeding $10 shall be paid in cheques, which shall be signed by the Treasurer and countersigned by one member of the Finance Committee.

Duties of Council.

32. The Council shall have general supervision of the affairs of the Society, shall prepare by-laws, shall approve and classify candidates before submitting their names to ballot, shall fill up vacancies as they occur amongst its members, shall apply funds in the treasury, shall recommend the amount of appropriations for specific purposes, and shall present a report on the affairs of the Society, embracing the report of the Treasurer, at the Annual Meeting. In no case shall the Council incur any expenditure for extraordinary

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purposes unless previously authorized to do so at the Annual Meeting or at a special general meeting.

Meetings of Council.

The Council shall meet as often as the business of the Society may require.

Composition and Duties of standing Committees.

33. The Council shall meet within one week after its election, and shall appoint, firstly, a standing committee of five on Finance, which shall have supervision of the accounts of the Society; secondly, an Auditor, who shall audit the books of the Treasurer and shall certify to his Annual Report; and, thirdly, a Library and House Committee of five, which shall have supervision of the rooms and library, and shall expend for the purchase of books or other articles of permanent value to the Society such sums as may be granted for that purpose. The Council shall also appoint a Secretary, a Treasurer and such subordinate officers as may be necessary for the proper conduct of the business of the Society at such salaries as it may deem fit. All officers having the funds of the Society in hand shall be required to give adequate bonds. The Secretary and Treasurer shall have seats and votes on the Council.

34. Three members of a standing Committee shall constitute a quorum thereof. Any member of a standing Committee who shall have failed to attend all regularly called meetings of the Committee during two months may be replaced by a vote of the Council.

Nomination and Election of Officers.

Nomination and Election of Officers.

35. A Nominating Committee of eight Voting Members, elected annually, and of the last three surviving Past Presidents, who continue to be Members, shall draw up a list of names of such Voting Members, as, in its opinion, are qualified to fill the offices of President, Vice-Presidents, and Councillors for the ensuing year, and who shall, previously to their names being entered on the list, have signified to the Committee, in writing, their willingness to accept their several nominations.

This list shall contain at least 31 names of members, viz.; one for President, five for Vice-Presidents, twenty-five for Councillors, and of the twenty-five nominated as Councillors at least eight shall be representative of the four sectional departments, not less than two for each, and at least ten of the twenty-five must be resident at headquarters. Amongst the ten resident at headquarters must be included at least four representatives of sections, at least one for each section, nominated as such. The list shall be signed by a majority of the Nominating Committee."

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Dates on which list must be submitted.

36. The Nominating Committee shall forward this list to the Council not later than the 1st of October of the current year, and a copy of the list shall be sent by the Secretary to each Voting Member of the Society not later than the fifteenth of the said October.

Additional nominations.

37. Any twelve Voting Members, of whom not more than four may be Associate Members, may present to the Council, on or before the fifteenth of November of the current year, a list of names proposed by them for officers, such list to be accompanied by the nominees' acceptance of nomination in writing. A copy of such list shall also be sent by the Council to each Voting Member not later than the following first of December.

Names of Nominators to be printed on list.

38. The list issued by the Nominating Committee shall be headed as such; and the names of the nominators of any list, other than that issued by the Nominating Committee, shall be printed at the head of such list as the nominators of the same.

Withdrawal of consent.

39. Should any Member, who has consented to be nominated for any office, wish to withdraw his consent, he must do so in writing not later than the fifteenth of September of the current year.

Ballot for Election of Officers.

40. The officers shall be elected by a majority of votes taken by sealed letter ballot. This ballot shall be opened and declared at the Annual Meeting, and the report of the scrutineers shall give the names of all Members who have been elected and number of votes cast for each. In case two or more persons shall equally have received the highest number of votes, the choice shall be made from amongst them by ballot at the meeting.

Persons elected for two offices.

40*a*. Any Member may vote for the same person for the offices of President, Vice-President and Member of Council, provided always that, should any Member be elected to more than one office, he must choose which he shall hold, and the vacancy arising from his declining to hold the extra office or offices shall be filled by the Member or Members who shall have received the next highest number of votes, after those already elected to said office or offices.

Appointment of Scrutineers.

41. The scrutineers of the ballot at the Annual Meeting for the election of officers and of the elective members of the Nominating Committee may be named, with the consent of the meeting, by the Chairman. If not thus named they shall be elected by ballot at the meeting.

ELECTION OF THE NOMINATING COMMITTEE.

Nominating Committee.

42. The Secretary shall send to all Voting Members, at the same time as he sends the list of Members nominated for office, a form of ballot (Form Z) for the election of the elective members of the Nominating Committee. The Voting Members shall elect represent-

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atives on the Nominating Committee as follows: those resident in Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick, one member; those resident in the Province of Quebec, two members; those resident in the Province of Ontario, three members; those resident in Canada to the west and north-west of the Province of Ontario, one member; and those not living in Canada or Newfoundland, one member, who shall be resident at headquarters.

It shall not be necessary for any member of the Nominating Committee to reside in the District he represents.

Ballot for Nominating Committee.

43. The ballot for election of members of the Nominating Committee shall be returned to the Secretary of the Society with the ballot for election of officers, and shall be examined and reported on by scrutineers appointed at the same time and in the same manner as the scrutineers for the ballot for the election of Officers.

The Member or Members for each district who shall receive the greatest number of votes shall form the elective part of the Nominating Committee, provided that in case any Member with a majority of votes refuse to act, the Member coming next in order by majority of votes shall be elected, provided, however, that, should the full number of the Committee still fail to be elected, the deficiency shall be supplied by ballot at the Annual Meeting.

Election of Chairman.

The Committee shall elect a Chairman within sixty days of their election, by each Member sending his vote sealed with his name outside the envelope, which shall be endorsed "Vote for Chairman," to the Secretary of the Society, whose duty it shall be, when he has received all the votes, to lay the same before the Council, which shall open the ballot, and notify (through the Secretary) the member of the Committee who has been elected Chairman. Should the Committee fail to elect a Chairman within the sixty days above mentioned, the Council shall make the appointment and notify the Committee thereof.

MEETINGS.

44. The meetings of the Society shall be as follows:—

Annual Meeting.

(A.) The Annual Meeting for the election of officers shall be held on the second Tuesday in January, or on such other day in January as the Council may direct. The Council shall lay before the meeting a report of the standing of the Society, with a statement by the Treasurer, certified by the Auditor of the funds of the Society, and the receipts and payments during the year ended on the 31st December preceding. Also a list of the meetings

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held by the Council and the names of those present at each meeting. At such Annual Meetings, fifteen Voting Members shall constitute a quorum. A notice of twenty-one days shall be required for an Annual Meeting. Annual Report.

(B.) Special General Meeting of the Society may be called by order of the Council for the transaction of special business. The quorum at a Special General Meeting shall be fifteen Voting Members. Special General Meeting.

A notice of twenty-one days shall be given for a Special General Meeting.

(C.) Ordinary meeting of the Society or of one of the Sections thereof shall be held on such Thursdays as may be arranged by the Council at eight o'clock in the evening during the months of October, November, December, January, February, March and April; but it shall be in the power of an ordinary meeting to make such special changes in these dates as may be deemed advisable. Ordinary Meeting.

The business of an ordinary meeting shall be transacted as nearly as possible in the following order:— Order of Business.

(a.) The minutes of the preceding meeting to be read, approved and signed by the Chairman and Secretary.

(b.) Business arising out of the minutes to be discussed.

(c.) Appointment of Scrutineers and opening of ballot for election of Members.

(d.) Candidates for admission into the Society to be announced.

(e.) Communications from the Council to be considered.

(f.) New business to be proposed and notices of motion to be given.

(g.) Original papers to be read and discussed.

(D.) Students' meetings shall be held at eight o'clock in the evening, at such dates as shall be determined by Council, and of which due notice shall be given. Students' Meetings

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Change in rules or special expenditure requires notice of motion.

45. Changes in the rules and regulations of the Society and new rules and regulations shall not be voted on or adopted, nor shall the expenditure of any funds, for which a vote is necessary, be authorized, unless notice of motion has been given not less than four weeks previously to such vote being taken, so that the Secretary shall have time to notify all Voting Members.

Papers.

Papers.

46. All papers must be forwarded to the Secretary of the Society, when they will be examined by the Council, and, if deemed of sufficent interest, copies shall be made and sent to every branch of the Society. Such papers shall be read and presented for discussion at all branches at the same time as at the headquarters of the Society. or as soon thereafter as may be practicable. A report of the discussion at the branches shall be forwarded to the Secretary of the Society within one week after the day fixed for the reading by the Society.

Papers the property of the Society.

47. The papers shall be the property of the Society, and no publication of any papers or discussion shall be made, except by the Society or with permission of the Council.

Amendments to By-Laws.

Mode of Amending By-Law.

48. New by-laws or alteration or repeal of existing by-laws may be made in the following manner:—Notification of proposed new by-laws or of alteration or repeal of existing by-laws shall be given to the Council, signed by at least ten Voting Members, not later than three months before the date of the Annual Meeting.

The Council shall issue notice of the proposition, specifying the particular new by-law or alteration or repeal of any existing by-law which may be thus recommended, and submit the same to vote by letter ballot, not less than two months before the Annual Meeting, the ballot to be taken on or before the date of the Annual Meeting, and not less than two-thirds of the votes cast shall be required to effect any change. The Council may also propose new by-laws, or alterations, or repeal of existing by-laws, and may submit the same to vote by letter ballot as above.

Branches.

Branches

49. A local branch of the Society may be established under the authority of the Council at the request of not fewer than ten Voting

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Members, who are desirous of forming themselves into such local branch in any place not less than one hundred miles from the headquarters of the Society. The Members of such branches shall consist of those who join from time to time. The establishment of a branch shall not release Members from any of their obligations to the Society, whether as regards fees or membership in any class.

Name of Branches.

50. Local branches, although formed strictly of Members of the Society, may be distinguished by the name of their locality, as, for example, "The.....Branch of the Canadian Society of Civil Engineers."

Officers of Branches.

51. The officers of local branches shall be a Chairman and Secretary-Treasurer, who shall be elected by the Members of the Branch.

Election of Members of Local Branches.

52. Corporate Members of local branches must have been elected by the Society in the usual way, but local branches may have the option of admitting to their meetings persons not members of the Society, under such regulations as such local branches may make. Members of branches elected in this way shall be called "Associates of the.....branch."

Fees of Members of Branches.

53. Corporate Members of a local branch shall pay to the Society the ordinary fees for non-resident members, and the Society shall remit to the branch on application of its Secretary-Treasurer, the sum of two dollars for each Corporate Member of the said Local Branch who has paid his fees for the current year. The Society shall not be liable for any expenses incurred by a branch.

Meetings of Branches.

54. Local branches may arrange to have the papers of the Society read before them at any time not earlier than one week after they have been read at headquarters, and the discussion may be sent to the Secretary of the Society for presentation at headquarters, and for publication in the transactions, if approved by the publishing Committee.

Rules for Branches.

55. In by-laws, rules of order, etc., and in particulars not specially referred to, the branches shall conform to the methods and rules adopted by the Society.

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CODE OF ENGINEERING ETHICS.

Duty of the Engineer to his Client.

56. Every member of the Society should perform the work he undertakes to do to the best of his ability and in the true spirit of his engagement, feeling it to be his duty to present all ascertained facts in their true light.

The Client's Obligation to the Adviser.

57. The Civil Engineer has a right to expect from his client the same consideration and deference to his opinion as is by their clients accorded to the members of other professions—Law and Medicine, for example—and without which the adviser should decline to advise. The surest way for the Engineer to obtain such necessary consideration and deference from the public will be found in his manner of carrying himself.

Mutual Relations of Chief and Assistant.

58. The Assistant Engineer must loyally obey and support his Chief, to whom it will be his duty to report directly on all matters relating to the work on which they may be jointly engaged. His report should be full and explicit on all important points, and exact to the best of the Assistant's knowledge and belief, cloaking nothing, even though going to show that previous reports had been inaccurate or not duly weighed, in some particulars affecting the well being of the business in hand.

59. The Assistant Engineer is entitled to look to his Chief for, and to receive from him, advice for his guidance in the proper performance of his duties, and, where right, to expect his support in matters in dispute between him (the Assistant) and his subordinates, or between him and the contractors working under him. He is also entitled to the aid of the Chief Engineer's professional experience or counsel where unlooked-for or extraordinary difficulties present themselves, or changes of original plan may be called for in the work on which they are associated, so that responsibility may be fairly apportioned between them.

Duties of Chief and Assistant.

60. It is the duty of both Chief and Assistant, each in his department, to study proper economy in the doing of the work, the management of which they have undertaken, and in every way consistent with the maintaining of the good character of the work to make the client's interest the guiding object.

Experiments in methods of work.

61. The Engineer may legitimately suggest experiments with a view to improvement, whether in methods of doing the work which he oversees, or for raising its character; but such experiments should only be undertaken with the full consent and co-operation of the person, whether client or contractor, on whom the expense may fall, and on the understanding that to them will accrue all pecuniary benefit from the success of the experiment.

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Unprofessional Conduct.

62. It shall be considered unprofessional for any Member of this Society to seek the position of an expert to report on any work that is in charge of a recognized Engineer.

63. It shall be the duty of any Engineer, before examining any work with a view to report thereon, to give the Engineer due notice before going on with the investigation, in order that he may have every facility to explain and sustain his methods of carrying on the work in question.

Professional Services of Engineers to each other.

64. Interchange of professional assistance between Members, as tending to promote fraternal intercourse and mutual good-will, is not to be discouraged, but neither is it to be considered obligatory on a Member to respond to the request of a Fellow Member for professional counsel or assistance. Service so rendered must be entirely voluntary on the part of the Member whose aid is sought.

Pecuniary Matters, Advertising, etc.

65. The Civil Engineer may, consistently with professional status, take out patents for new inventions or for improvements on old ones, and may sell or otherwise dispose of the patents for his own advantage. He may undertake surveys and the engineering of works by contract, or he may take contracts for the construction of works on a percentage of their cost. Advertising with a view to attracting business should, where resorted to, be as far as possible free from egotistic or self-laudatory references, and expressed in language not derogatory to the dignity of the profession.

Duties of Engineer to the Public.

66. The Civil Engineer, whose advice is sought in respect to the usefulness, practicability, and cost of work, should, before expressing his opinion, obtain reliable information on all points involved in the matter submitted to his judgment, including the probable paying capacity of the contemplated undertaking. He must be cautious how he recommends large preliminary outlay, should avoid connecting himself with schemes or projects of merely speculative character, always bearing in mind that his professional reputation will be to a great extent judged by the inherent merits and commercial value of the undertakings with which his name may come to be associated.

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MANITOBA ACT.

An Act respecting the profession of Civil Engineers.

ACT LIX. VICTORIA, CHAPTER 2.

[*Assented to 19th March, 1896.*]

Preamble.

Whereas, it is deemed expedient for the better protection of the public interests and for the general advancement of Mechanical Science, and more particularly for promoting the acquisition of that species of knowledge which has special reference to the profession of a Civil Engineer, and to encourage investigation in connection with the profession, and in order to enable persons requiring professional aid in any work, to which such knowledge of Civil Engineering is applicable or necessary, to distinguish between qualified and unqualified Civil Engineers;

Therefore,

Her Majesty, by and with the advice and consent of the Legislative Assembly of the Province of Manitoba, enacts as follows:—

Short title.

1. This Act may be cited as "The Manitoba Civil Engineers' Act."

Incorporation of the Canadian Society of Civil Engineers.

2. The Civil Engineers of Canada, heretofore incorporated by an Act of the Parliament of Canada, being Chapter 124 of the Acts passed at the Session held in the 50th and 51st years of Her Majesty's reign, under the name and style of "The Canadian Society of Civil Engineers," shall be a body corporate by the name aforesaid, having perpetual succession and a common seal, with power to acquire, hold and dispose of real and personal property for the purposes of its constitution, and to sue and to be sued in the manner usual with such corporations.

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Members.

3. All persons who, on the day this Act comes into force, are members of the said existing Canadian Society of Civil Engineers, and all persons who shall hereafter be admitted as members of the Society hereby incorporated, and who shall be registered under the provisions of this Act, shall be members of the said Society.

Council.

4. There shall be a Council of Management of the said Society, to be appointed in the manner provided for in this Act, and hereinafter referred to as "the Council."

How composed

5. The Council shall be composed of twenty-one persons, who shall, in the first instance, and as a Provisional Council, consist of the present Council of the existing Canadian Society of Civil Engineers, if British subjects and residing within the Dominion of Canada.

First meeting of Council.

6. The members of the said Provisional Council shall meet in the city of Winnipeg for the purpose of organization, within two months after the passing of this Act, at such time and place as may be set forth in a notice in the *Manitoba Gazette*, and at such meeting any five members of the Council shall form a quorum.

First general meeting.

7. A general meeting of the members of the Society shall be called by the Provisional Council, on or before the first day of February next, after the passing of this Act, for the election of a permanent Council. The time and place for such meeting shall be determined by the Provisional Council, and at least two weeks' notice in writing shall be given by the Secretary to each member of the Society, and such meeting and any subsequent meeting of the Society may be held without this Province, but in the Dominion of Canada, as the Council may from time to time determine.

Permanent Council.

8. All members of the permanent Council shall be elected by ballot, each member having one vote, and the member or members obtaining the greatest number of votes shall be declared elected.

Terms of office.

9. The members of the Council so elected shall hold office for the following terms respectively:—

The seven names who have received the greatest number of votes shall hold office for the term of three years, the next seven

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names for the term of two years, and the third and last seven names for the term of one year.

Qualifications.

10. No person shall be eligible for election to the Council, or qualified to fill any vacancy therein, or to vote for any member thereof at the first election, unless at such time he shall be a duly qualified member of the said existing Canadian Society of Civil Engineers; and no person shall be eligible for election to the Council, or qualified to fill any vacancy therein, or to vote for any member thereof at any subsequent election unless duly qualified under the provisions of this Act and the By-laws of the Society.

Vacancy.

11. In the case of the death or resignation of any members of the Council, the other members of the Council shall have power to fill all vacancies so caused until the time of the holding of the next annual meeting.

Meetings.

12. Meetings of the Society and Council shall be held at such times and places as may be fixed by by-law of the Society, and at all meetings of the Society or Council the President or Chairman for the time being shall have a casting vote.

Power to enact By-Laws, etc.

13. The Council shall have full power to enact by-laws for:

(a.) The qualification, election and registration of members of the Society.

(b.) The appointment and removal and defining the functions and duties of all officers and servants of the Society, and their remuneration, the time and place of holding meetings of the Society and Council, and the notice to be given therefor.

(c.) The calling of all meetings, the quorum and the procedure in all things at such meetings.

(d.) The suspension, expulsion, disciplining and admission of members.

(e.) The appointment of examiners for the purpose of ascertaining and reporting upon the qualifications of persons who shall present themselves for admission and enrollment as students at any examination.

(f.) The admission and regulation of students, the periods and conditions of study, and all matters relating to the discipline and honour of the profession.

(g.) The regulating and fixing of the admission and annual

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fees payable by members and students. And to deal with and regulate all other matters necessary for the government of the Society, and to effectually carry out its objects, and generally to administer the affairs of the Society.

Repeal of By-laws, etc.

14. The Council may from time to time repeal, amend and re-enact the by-laws of the Society; but every such by-law and every repeal, amendment and re-enactment thereof, unless in the meantime confirmed at a General Meeting of the Society, duly called for that purpose, shall only have force until the next Annual Meeting of the Society, and in default of confirmation thereat, shall, at and from that time only, cease to have force, and in that case no new by-law to the same or like effect shall have any force until confirmation at a General Meeting of the Society.

Registrar.

15. The Council shall cause to be kept by an officer appointed by it, to be called the Registrar, a book or register, in which shall be entered the name of every person registered as a member of the Society, according to the provisions of this Act, and those persons only whose names are inscribed in the book or register above mentioned shall be deemed to be members of the Society, and such book or register shall at all reasonable times be open for inspection by any members of the Society or by any other person.

Penalty for false registration.

16. If the Registrar shall wilfully make or cause to be made any falsification in any matter relating to the register, or shall refuse to allow the register to be inspected, he shall be deemed to be guilty of a misdemeanour, and shall on conviction thereof be imprisoned for any term not exceeding twelve months.

Right to title of Civil Engineer

17. On and after the 1st day of July, 1896, no person shall be entitled within this Province to take or use the name and title of "Civil Engineer" or any abbreviation thereof, either alone or in combination with any other word or words, or any name, title or description implying that he is a member of the said Society of Civil Engineers, or act as Engineer in laying out, advising on, constructing or superintending the construction of any railway or public work, or any work upon which public money is expended, the cost of which shall exceed $500, unless such person is a member of the Society hereby incorporated and registered as such under the provisions of this Act, or unless he is a duly qualified Civil En-

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gineer, and entitled to use the title of Civil Engineer by virtue of some statute in force in this Province, or by the authority of some institution of learning in this Province having authority to confer degrees in Civil Engineering, or unless he has been practising as a Civil Engineer in this Province at the time of the passing of this Act, or unless he is a member in good standing of some institution of Civil Engineers in Great Britain and Ireland, or of some National Society of Civil Engineers of good standing in any foreign country.

Act deemed public Act.

18. This Act shall be deemed a Public Act.

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QUEBEC ACT.

An Act Concerning Civil Engineers.

Vic. 61, Chap. 32.

And amendment thereto by the addition of sub-head (d) to Article 3.
Act 2 Ed. VII., Chap. 25.

Whereas by an Act of the Parliament of Canada, 50-51 Victoria, chapter 124, "The Canadian Society of Civil Engineers" was incorporated, and it is deemed advisable to establish the qualifications necessary to permit persons to act or practice as civil engineers in the Province of Quebec;

Therefore, Her Majesty, by and with the advice and consent of the Legislature of Quebec, enacts as follows:—

1. The following expressions in this act have the meanings hereby assigned to them, unless there is something in the text repugnant to such construction:

(a) The expression: "the society," means the Canadian Society of Civil Engineers.

(b) The expression: "the council," means the council of the said society.

(c) The expression: "corporate member," means a member or associate member of the said society.

(d) The expression: "civil engineer," means any one who acts or practices as an engineer in advising on, in making measurements for, or in laying out, designing or supervising the construction of railways, metallic bridges, wooden bridges, the cost of which exceeds $600.00, public highways requiring engineering knowledge and experience, roads, canals, harbours, river improvements, light-houses, and hydraulic, municipal, electrical, mechanical, or other engineering works, not including government colonization roads or ordinary roads in rural municipalities; but it is not deemed to apply to a mere skilled artisan or workman.

2. On and after the 1st of January, 1899, no person shall be entitled, within the Province of Quebec, to use the title of civil engineer, or any abbreviation thereof, or any name, title or descrip-

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tion implying that he is a corporate member of the said society, nor to act or practice as civil engineer within the meaning of the first section of this act:

(a) Unless such person is a corporate member of the society or becomes such under the provisions of this act; or,

(b) Unless he is entitled, by some statute of the Dominion of Canada, of the late Province of Canada, or of the Province of Quebec, to use the title of civil engineer; or,

(c) Unless he is practicing as a civil engineer in this Province, and, within one year from the passing of this act, becomes a corporate member of the society; or,

(d) Unless he is a member of the corporation of land surveyors at the time of the passing of this act, and at any time thereafter becomes a corporate member of the society.

3. The following persons only shall, after the coming into force of this act, be admitted as corporate members of the Society to practice in the Province of Quebec:

(a) All persons, being practicing civil engineers within the Province, at the time of the coming into force of this act, who, within one year therefrom, apply for admission to and pay the subscription fees required under the by-laws of the society; the application must be supported by an affidavit verifying the allegations of the application;

(b) All persons who, having been admitted to study under the provisions of this act, shall have passed the prescribed examination and shall have been licensed as civil engineers by the society;

(c) All persons, being members of the corporation of land surveyors of this Province, at the time of the coming into force of this act, who, at any date thereafter, apply for admission to and pay the subscription fees required under the by-laws of the society.

(d) And whosoever hereafter establishes to the satisfaction of the Council that he was not a resident of this Province at the time of the coming into force of this act; that by reason of such absence he could not comply with its provisions, or give the periods of study and service required in the office or service of a corporate member of the Society; that he has, however, been practicing as a civil engineer, within the meaning of this act, for a period of not less than ten years, and that he is a member of the highest grade of the Institution of Civil Engineers, or any other national engineering society of similar standing; gives one month's notice and, at the same time, pays the society the sum of fifty dollars; and passes the examination prescribed in paragraph (e) of article 6 of this act.

4. A board of examiners, of not less than six persons, who shall be resident in the Province of Quebec, to examine candidates for

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admission to the study, or for admission to the practice of civil engineering, shall be constituted.

Four members of this board, two of whom must have the proper qualifications and competency to examine all candidates for preliminary and final examinations in French or in English, at the option of the candidate, shall be appointed by the council, one member by McGill University, and one by Laval University.

Three members of the board shall constitute a quorum.

The said board shall meet at least twice each year, at the cities of Quebec and Montreal alternately, on the first Tuesday in May and November.

5. A candidate for admission to study shall:

(a) Give one month's notice to the secretary of the society of his intention to present himself for examination, and at the same time shall pay such secretary the sum of twenty dollars as a fee, one-half of which shall be remitted in the event of failure to pass the prescribed examination;

(b) Produce a certificate of good character;

(c) Pass an examination in the following subjects, namely: general geography, that of Canada in particular; history of Canada; arithmetic; elements of geometry; use of logarithms; algebra, up to and including quadratic equations; trigonometry, up to and including the solution of plane triangles.

If successful, the candidate shall be entitled to a certificate that he has passed such examination.

If the candidate hold a certificate of having been admitted to study as a provincial land surveyor at the time of the coming into force of this act, then such certificate shall be accepted in place of the foregoing examination.

If the candidate hold a degree of Bachelor of Applied Science, Bachelor of Arts, Bachelor of Science, or Bachelor of Letters, conferred upon him by any Canadian or British university, or has graduated from and holds the diploma of the Royal Military College, or holds a diploma as provincial land surveyor in this Province, he shall, upon making satisfactory proof that he is the person named in such degree or diploma, be entitled, on payment of the above mentioned fee, to receive a certificate permitting him to study.

6. A candidate for admission to practice shall:

(a) Give one month's notice of his intention to present himself for examination, and, at the same time, pay the secretary the sum of forty dollars as a fee;

(b) Produce a certificate of good character;

(c) Establish that he is at least twenty-one years of age;

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(d) Establish that, since his admission to study, he has been engaged in the pursuit of engineering in the office or in the service of a corporate member of the society for a period of at least five years, or for a period of two years, if he holds a diploma as a Provincial land surveyor in this Province, or has a degree from any college or university in Canada granting degrees or diplomas in applied science after a course of not less than three years. Time occupied during college vacation, in actual engineering work, under the direction of a corporate member of the society, shall count towards the term of two years above mentioned.

(e) Pass an examination before the board of examiners of the society on the theory and practice of engineering, and specially in one of the following branches at his option: railway, municipal, hydraulic, mechanical, mining or electrical engineering.

2. Indentured pupils of civil engineers, at the time of the coming into force of this act, who shall, within six months thereafter, register their indentures with the society and pay the admission fees, shall, upon the completion of the full term of five years, be admitted to practice on passing the preliminary and final examinations as herein prescribed.

3. All examinations shall be conducted in French or English at the option of the candidate.

7. Any student who has passed the examination prescribed by this act is entitled to receive a diploma, and becomes a corporate member of the society.

8. No by-laws passed, or that may be passed, by the society, shall have force or effect in this Province until approved by the Lieutenant-Governor in Council.

9. No person practicing the profession of civil engineer, and not entitled to do so under this act, shall recover before any court of justice any sum of money for the professional services rendered in such practice.

10. Any person who, not being registered as a member of the said society, takes or makes use of any such name, title or designation as mentioned, or assumes the title of civil engineer, shall be liable upon summary conviction to a fine not exceeding twenty-five dollars for the first offence, and not exceeding one hundred dollars for any subsequent offence.

11. Nothing in this Act shall be deemed to encroach upon the rights and privileges conferred upon provincial land surveyors by any act of the Legislature of this Province.

12. This act shall come into force on the day of its sanction.

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BY-LAWS

of

The Canadian Society of Civil Engineers.

Applicable to the Province of Quebec under Act 61 Vic., Chap. 32, entitled "an Act concerning Civil Engineers."

Approved by the Lieutenant-Governor in Council Feb. 24th, 1899.

Classification of Corporate Members.

Qualification of Members.

7. Every candidate for election as Member must be at least thirty years of age, and must have been engaged in some branch of Engineering for at least ten years, which period may include apprenticeship, or pupilage in a qualified Engineer's office, or a term of instruction in some school of engineering recognized by the Council. The term of ten years will be reduced to eight years in the case of any candidate who has graduated with honours in his Engineering course. In every case the candidate must have had responsible charge of work for at least five years, and this not merely as a skilled workman, but as an engineer qualified to design or direct engineering work.

Qualification of Associate Members.

8. Every candidate for election as an Associate Member must have been engaged in some branch of Engineering for at least five years, which period may include apprenticeship or pupilage in a qualified Engineer's office, or a term of instruction in some school of engineering recognized by the Council.

Mode of promotion to several classes.

13. Proposals for transfer from one class to a higher (Form B in the Appendix) shall contain a statement over the candidate's signature, of his age, residence, and the nature and term of his professional service, also an agreement to conform to the regulations of the Society if promoted. The applicant shall give as references at least five Corporate Members, from whom the Council shall obtain satisfactory evidence in writing that they personally know the candidate, and that he is worthy of promotion.

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Notification of election.

15. On the election of a candidate, he shall be immediately notified by the Secretary (Form C in the Appendix). On receipt of the notification he must subscribe to the Constitution and By-Laws (in the terms set forth in Form D in the Appendix), and pay to the Treasurer the regular fees before he can be entitled to the privileges of membership.

Certificates of Membership.

16. All certificates of membership issued to Members are the property of the Society, and must be returned by any Member who has resigned, or whose name has been removed from the roll of membership, within one week of his receipt of notice of such removal or acceptance of resignation.

EXPULSION.

Expulsion.

17. Upon the request of ten or more Members, that, for causes specified, a Member of the Society should be expelled, the Council shall consider the matter, and, if there shall be sufficient reason, shall advise the said Member that his resignation will be accepted. He may upon demand receive a copy of the charges against him, and present a written defence. Two months after such action on his part the Council shall finally consider the case, and if resignation has not been tendered, or a satisfactory defence made, will then notify the Member that he will be expelled in one month unless he elects to appeal from this decision, in which case his appeal shall be voted on by letter ballot.

Neither the Council nor the Members bringing the charge shall vote. If two-thirds of the votes are for expulsion the Member shall be expelled, and the Council shall notify the said Member and the Society of the result. In case no appeal is made, the Council shall expel the said Member, and notify him and the Society of his expulsion, and such notification shall in any event be the only notice, public or private, taken of the matter.

Expulsion for criminal offence.

17*a*. If any Member of the Society shall be convicted of any criminal offence whatever, he shall *ipso facto* be disqualified from membership in the Society, and his name shall be erased from among the Members by the Secretary, acting upon the instruction of the Council of the Society.

DUES.

Definition of resident and non-resident Members.

18. Members, Associate Members, and Students who reside within fifty miles of the headquarters of the Society shall be deemed resident; those who reside beyond the limit of fifty miles shall be deemed non-resident.

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Annual Fees.

19. Each resident Member shall pay $10.00, and each non-resident Member, $8.00 per annum. Each resident Associate Member shall pay $8.00, and each non-resident Associate Member, $6.00 per annum. Each Student shall pay $2.00 per annum.

Resignation.

20. Every person admitted to the Society shall be liable for all dues until he shall have signified to the Secretary, in writing, his desire to withdraw, when, if his dues have been fully paid up, his name will be omitted from the list of membership.

Annual Fees due on Jan. 1st.

21. All annual subscriptions shall become due on the first day of January in each year for the year then commencing, but no Member shall be considered in arrears for any year until after the first day of April of that year. It shall be the duty of the Secretary to notify each Member of the amount due for the ensuing year, at the time of giving notice of the annual meeting.

22. Any Corporate Member in default of payment of dues shall be notified by the Secretary to pay such arrears within three months. In the event of failure to pay such arrears within the time stipulated, the Member so notified shall cease to be, for the time being, a Member of the Society, but shall be reinstated by the Council on paying the arrears of fees due.

Re-instatement on roll of Membership.

23. Any Member who, for non-payment of dues, has been struck off the roll of membership, may again, if the Council approve, join the Society on payment of all arrears, and on payment of such entrance fees as may hereafter be agreed upon.

Change in amount of Annual Fees.

24. The amount of the annual dues, to be paid for the support of the Society, may be changed from time to time at the Annual General Meeting of the Society, provided that notice of the intended action thereon shall have been given to the Members two months previously by circular. No alteration in the amount of said fee shall apply to the fiscal year during which it is made, but shall take effect on and after the first day of January next succeeding the date of such alteration. Those who become resident or non-resident by removal of residence shall be subject to the dues of the class to which they belong at the date of the Annual Meeting, as may be shown by the records of the Society, or by a written notice to the Secretary.

Compounding of Fees.

25. Any Member may compound his fee, and become a Life Member on payment of a sum of $150.00, which is to be invested by the Council, the interest only to be used for current expenses.

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Exemption from payment of dues.

26. The Council may, for sufficient cause, exempt from payment of annual dues any Member, distinguished in his professional career, who, from ill-health, advanced age, or for other good reason assigned, does not continue to carry on a lucrative practice, and is unable to pay such dues.

OFFICERS.

Officers

27. The officers of the Society shall consist of a President, three Vice-Presidents, a Treasurer, a Secretary, the last three surviving Past Presidents who continue to be Members, who shall be styled Honorary Councillors; and twenty Councillors. Of the twenty Councillors, not more than three may be Associate Members.

COUNCIL.

Composition.

28. There shall be a Council consisting of the President, Vice-Presidents, Treasurer, Secretary, Honorary Councillors and Councillors, and of this council five shall constitute a quorum. The Members of Council shall retain their position until their successors have been appointed.

MANAGEMENT.

Chairman of Society Meetings.

29. The President, or, in his absence, one of the Vice-Presidents, or, in their absence, a Member of Council, shall preside at all meetings of the Society. In the event of the absence of the President and of all the Vice-Presidents and Members of Council, the meeting may select any Member as Chairman.

Duties of Secretary.

30. The Secretary shall keep an acurate record of the transactions of the Society and of the Council. He shall also keep a correct roll of Members' names with their addresses and dates of their admission. He shall conduct the correspondence of the Society, give notice of all meetings, supervise the printing, and, under the direction of the Council, edit the transactions of the Society.

Duties of Treasurer.

31. The Treasurer shall have charge of the funds of the Society, shall receive all money and pay all accounts and orders approved of by the President, or by the Finance or Library and House Committee. He shall also deposit and invest the funds of the Society in its name, and always with the approval of the Council. All accounts exceeding $10 shall be paid in cheques, which shall be signed by the Treasurer and countersigned by one member of the Finance Committee.

Duties of Council.

32. The Council shall have general supervision of the affairs of the Society, shall prepare by-laws, shall approve and classify candi-

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dates, before submitting their names to ballot, shall fill up vacancies as they occur amongst its members, shall apply funds in the treasury, shall recommend the amount of appropriations for specific purposes, and shall present a report on the affairs of the Society, embracing the report of the Treasurer, at the Annual Meeting. In no case shall the Council incur any expenditure for extraordinary purposes unless previously authorized to do so at the Annual Meeting or at a special general meeting.

The Council shall meet as often as the business of the Society may require.

Meetings of Council.

33. The Council shall meet within one week after its election, and shall appoint, firstly, a standing committee of five on Finance, which shall have supervision of the accounts of the Society; secondly, an Auditor, who shall audit the books of the Treasurer and shall certify to his Annual Report; and, thirdly, a Library and House Committee of five, which shll have supervision of the rooms and library, and shall expend for the purchase of books or other articles of permanent value to the Society such sums as may be granted for that purpose. The Council shall also appoint a Secretary, a Treasurer and such subordinate officers as may be necessary for the proper conduct of the business of the Society at such salaries as it may deem fit. All officers having the funds of the Society in hand shall be required to give adequate bonds. The Secretary nd Treasurer shall have seats and votes on the Council.

Composition and duties of Standing Committees.

Finance' Committee.

Library Committee.

34. Three members of standing Committee shall constitute a quorom thereof. Any member of a standing Committee who shall have failed to attend all regularly called meetings of the Committee during two months may be replaced by a vote of the Council.

Nomination and Election of Officers.

35. A Nominating Committee of eight Corporate Members, elected annually, and of the last three surviving Past Presidents, who continue to be Members, shall draw up a list of names of such Corporate Members as, in its opinion, are qualified to fill the offices of President, Vice-Presidents, and Councillors for the ensuing year and who shall, previously to their names being entered on the list, have signified to the Committee, in writing, their willingness to accept their several nominations.

Nomination and Election of Officers.

This list shall contain at least thirty-one names of Corporate Members, viz.: one for President, five for Vice-Presidents, and twenty-five for Councillors; and of the twenty-five nominated as Councillors, at least seven must be resident at headquarters. The ist shall be signed by a majority of the Nominating Committee.

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Dates on which list must be submitted.

36. The Nominating Committee shall forward this list to the Council not later than the first of October of the current year, and a copy of the list shall be sent by the Secretary to each Corporate Member of the Society not later than the fifteenth of the said October.

Additional nominations.

37. Any twelve Corporate Members, of whom not more than four may be Associate Members, may present to the Council, on or before the fifteenth of November of the current year, a list of names proposed by them for officers, such list to be accompanied by the nominees' acceptance of nomination, in writing. A copy of such list shall also be sent by the Council to each Corporate Member not later than the following first of December.

Names of nominators to be printed on list.

38. The list issued by the Nominating Committee shall be headed as such; and the names of the nominators of any list, other than that issued by the Nominating Committee, shall be printed at the head of such list as the nominators of the same.

Withdrawal of consent.

39. Should any Corporate Member, who has consented to be nominated for any office, wish to withdraw his consent, he must do so in writing not later than the fifteenth of September of the current year.

Ballot for Election of Officers.

40. The officers shall be elected by a majority of votes taken by sealed letter ballot. This ballot shall be opened and declared at the Annual Meeting, and the report of the scrutineers shall give the names of all Members who have been elected and number of votes cast for each. In case two or more persons shall equally have received the highest number of votes, the choice shall be made from amongst them by the ballot at the meeting.

Persons elected for two Offices.

40*a*. Any Member may vote for the same person for the offices of President, Vice-President and Member of Council, provided always that, should any Member be elected to more than one office, he must choose which he shall hold, and the vacancy arising from his declining to hold the extra office or offices shall be filled by the Member or Members who shall have received the next highest number of votes, after those already elected to said office or offices.

Appointment of Scrutineers.

41. The scrutineers of the ballot at the Annual Meeting for the election of officers and of the elective members of the Nominating Committee may be named, with the consent of the meeting, by the Chairman. If not thus named they shall be elected by ballot at the meeting.

ELECTION OF NOMINATING COMMITTEE.

Nominating Committee.

42. The Secretary shall send to all Corporate Members, at the same time he sends the list of those nominated for office, a form of ballot (Form Z) for the election of the elective members of the Nominating Committee. The Corporate Members shall elect representatives

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on the Nominating Committee as follows: Those resident in Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick, one member; those resident in the Province of Quebec, two members; those resident in the Province of Ontario, three members; those resident in Canada to the west and north-west of the Province of Ontario, one member; and those not living in Canada or Newfoundland, one member, who shall be resident at headquarters.

It shall not be necessary for any member of the Nominating Committee to reside in the District he represents.

Ballot for Nominating Committee.

43. The ballot for election of members of the Nominating Committee shall be returned to the Secretary of the Society with the ballot for election of officers, and shall be examined and reported on by scrutineers appointed at the same time and in the same manner as the scrutineers for the ballot for the election of Officers.

The Member or Members for each District who shall receive the greatest number of votes shall form the elective part of the Nominating Committee, provided that, in case any Member with a majority of votes refuse to act, the Member coming next in order by majority of votes shall be elected, provided, however, that, should the full number of the Committee still fail to be elected, the deficiency shall be supplied by ballot at the Annual Meeting.

Election of Chairman.

The Committee shall elect a Chairman within sixty days of their election, by each Member sending his vote, sealed, with his name outside the envelope, which shall be endorsed "Vote for Chairman," to the Secretary of the Society, whose duty it shall be, when he has received all the votes, to lay the same before the Council, which shall open the ballot, and notify (through the Secretary) the member of the Committee who has been elected Chairman. Should the Committee fail to elect a Chairman within the sixty days above mentioned, the Council shall make the appointment and notify the Committee thereof.

MEETINGS.

44. The meetings of the Society shall be as follows:—

Annual Meeting.

(A.) The Annual Meeting for the election of officers shall be held on the second Tuesday in January, or on such other day in January as the Council may direct. The Council shall lay before the meeting a report of the standing of the Society, with a statement by the Treasurer, certified by the Auditor, of the funds of the Society, and the receipts and payments during the year ended on the 31st December preceding. Also a list of the meetings held by the Council and the names of those present at each meeting. At such annual meetings fifteen Corporate Members shall constitute a quorum. A notice of twenty-one days shall be required for an Annual Meeting.

Annual Report.

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Special General Meeting.

(B.) Special General Meeting of the Society may be called by order of the Council for the transaction of special business. The quorum at a Special General Meeting shall be fifteen Corporate Members.

A notice of twenty-one days shall be given for a Special General Meeting.

Ordinary Meeting.

(C.) Ordinary meetings of the Society or of one of the Sections thereof shall be held on such Thursdays as may be arranged by the Council at eight o'clock in the evening during the months of Oct., Nov., December, January, February, March and April; but it shall be in the power of an ordinary meeting to make such special changes in these dates as may be deemed advisable.

Order of Business.

The business of an ordinary meeting shall be transacted as nearly as possible in the following order:—

(a.) The minutes of the preceding meeting to be read, approved and signed by the Chairman and Secretary.

(b.) Business arising out of the minutes to be discussed.

(c.) Appointment of Scrutineers and opening of ballot for election of members.

(d.) Candidates for admission into the Society to be announced.

(e.) Communications from the Council to be considered.

(f.) New business to be proposed and notices of motion to be given.

(g.) Original papers to be read and discussed.

Students' Meetings.

(D.) Students' meetings shall be held at eight o'clock in the evening, at such dates as shall be determined by Council, and of which due notice shall be given.

Changes in rules or special expenditures require notice of motion.

45. Changes in the rules and regulations of the Society and new rules and regulations shall not be voted on or adopted, nor shall the expenditure of any funds, for which a vote is necessary, be authorized, unless notice of motion has been given not less than four weeks previously to such vote being taken, so that the Secretary shall have time to notify all Corporate Members.

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Papers.

Papers.

46. All papers must be forwarded to the Secretary of the Society, when they will be examined by the Council, and, if deemed of sufficient interest, copies shall be made and sent to every branch of the Society. Such papers shall be read and presented for discussion at all branches at the same time as at the headquarters of the Society, or as soon thereafter as may be practicable. A report of the discussion at the branches shall be forwarded to the Secretary of the Society within one week after the day fixed for the reading by the Society.

Papers the property of the Society.

47. The papers shall be the property of the Society, and no publication of any papers or discussion shall be made, except by the Society or with the permission of the Council.

Amendments to By-Laws.

Mode of amending By-Laws.

48. New by-laws or alteration or repeal of existing by-laws may be made in the following manner. Notification of proposed new by-laws or of alteration or repeal of existing by-laws shall be given to the Council, signed by at least ten Corporate Members, not later than three months before the date of the Annual Meeting.

The Council shall issue notice of the proposition, specifying the particular new by-law or alteration or repeal of any existing by-law which may be thus recommended, and submit the same to vote by letter ballot, not less than two months before the Annual Meeting, the ballot to be taken on or before the date of the Annual Meeting, and not less than two-thirds of the votes cast shall be required to effect any change. The Council may also propose new by-laws, or alterations, or repeal of existing by-laws, and may submit the same to vote by letter ballot, as above.

Branches.

Branches.

49. A local branch of the Society may be established under the authority of the Council at the request of not fewer than ten Voting Members, who are desirous of forming themselves into such local branch in any place not less than one hundred miles from the headquarters of the Society, or from any existing branch. The Members of such branches shall consist of those who join from time to time. The establishment of a branch shall not release Members from any of their obligations to the Society, whether as regards fees or membership in any class.

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Name of Branches.

50. Local branches, although formed strictly of Members of the Society, may be distinguished by the name of their locality, as, for example, "The.....Branch of the Canadian Society of Civil Engineers."

Officers of Branches.

51. The officers of local branches shall be a Chairman and Secretary-Treasurer, who shall be elected by the Members of the Branch.

Election of Members of Local Branches.

52. All classes of Members of local branches must have been elected by the Society in the usual way, and in no case shall their Members be added to locally or otherwise than in the regularly prescribed way.

Fees of Members of Branches.

53. Members of a local branch shall pay to the Society the fees of a resident member of the Society, and the Society shall remit to the branch, on application of its Secretary-Treasurer, the difference between a resident and non-resident's fees. The Society shall not be liable for any expenses incurred by a branch.

Meetings of Branches.

54. The regular meetings in all branches shall be held on the same date as the corresponding meetings of the Society at headquarters.

Rules of Branches.

55. In by-laws, rules of order, etc., and in particulars not specially referred to, the branches shall conform to the methods and rules adopted by the Society.

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APPENDIX.

FORM A.

The Canadian Society of Civil Engineers.

The proposal for MEMBER, ASSOCIATE-MEMBER, ASSOCIATE, or STUDENT † shall contain a statement, over the *candidate's signature*, of his *age, residence*, the nature and term of his *professional service*, and that he will conform to the requirements of membership if elected.

STATEMENT.

I, ...

residing at.....

being desirous of admission into the Canadian Society of Civil Engineers, beg to submit the following as my professional record :

I was born at.....*on*.....*18*

(The Candidate must here insert a concise history, with dates, of his professional career, specifying the positions he has held, the nature and extent of the works upon which he has been engaged, and his present profession and occupation. Proper names and names of railroads must be written in full.)

I will conform to the requirements of the class to which I may be elected.

(Signature)—.....

(P.O. Address).....

Date.....*190*

I submit below the names of five Voting Members as references.

† One signature sufficient for Student. By-Law 13.

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FORM B.

The Canadian Society of Civil Engineers.

The proposal for TRANSFER FROM ONE CLASS TO A HIGHER shall contain a statement, over the *candidate's signature*, of his *age*, *residence*, the nature and term of his *professional service*, and that he will conform to the requirements of the class to which he may be transferred.

STATEMENT.

I, ...

residing at .....

being .....

of the Canadian Society of Civil Engineers beg to submit the following as my professional record, and request to be transferred to the class of

.....

I was born at .....*on* *18*

(The Candidate must here insert a concise history, with dates of his professional career, specifying the positions he has held, the nature and extent of the works upon which he has been engaged, and his present profession or occupation. Proper names and names of railways must be written in full.)

I will conform to the requirements of the class of .....

(Signature) .....

(P.O. Address) .....

Date *190*

I submit below the names of five Voting Members of the Society as references.

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FORM C.

The Canadian Society of Civil Engineers.

MONTREAL,.....190

SIR,

I have the honour to inform you that you were duly elected

.....

of THE CANADIAN SOCIETY OF CIVIL ENGINEERS, *on the*.....

.....*day of*.....

According to the regulations of the Society you are required as.....

.....*to pay* $.....*being your subscription for the Current year, and to return the accompanying Form D, with your signature, within six months of the date of your election; otherwise your election will be cancelled. These conditions being complied with you will be considered as admitted into the Society, when any publications or notices to which you are entitled will be forwarded according to your directions.*

I beg to call your attention to Section 22 of the By-Laws.

I am, Sir,

Yours, &c.,

Secretary.

FORM D.

I, the undersigned, being elected.....

of THE CANADIAN SOCIETY OF CIVIL ENGINEERS, *agree to be governed by the Charter and By-Laws of the Society. I will promote the objects of the Society as far as shall be in my power, and attend the meetings thereof as often as I conveniently can. Provided that whenever I shall signify in writing to the Secretary, for the time being, that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.*

I also engage to present to the Society an original communication, a drawing, plan, or model of engineering interest, or some scientific work for the library, within the space of twelve months from the date of my election.

(Signature).....

(P.O Address).....

Date *190*

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FORM Z.

The Canadian Society of Civil Engineers.

BALLOT FOR THE ELECTION OF THE ELECTIVE MEMBERS OF THE NOMINATING COMMITTEE FOR THE YEAR 190 .

District of _____

Write in above "Maritime Provinces," "Quebec," "Ontario," "North-West Provinces," or "outside of Canada and Newfoundland."

(Write in the above space the name or names of members whom you wish to represent your district in accordance with By-Law No. 42. This list is to be enclosed in the envelope marked "BALLOT FOR NOMINATING COMMITTEE," *and is to be further enclosed in the large envelope marked* "BALLOT FOR THE ELECTION OF THE NOMINATING COMMITTEE FOR 190 ," *and returned to the Secretary on or before January 190 .)*

[Extract from By-Law No. 42.]

"The voting members shall elect representatives on the Nominating Committee as follows:—Those resident in Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick, one member;—those resident in the Province of Quebec, two members; those resident in the Province of Ontario, three members; those resident in Canada to the West and North-West of the Province of Ontario, one member; and those not living in Canada or Newfoundland, one member, who shall be resident at headquarters."

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LIST OF MEMBERS

OF THE

Canadian Society of Civil Engineers.

FEBRUARY 1st, 1905.

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NOTICE.

It is particularly requested that changes of address be immediately communicated to

The Secretary,

Canadian Society of Civil Engineers,

877 *Dorchester St.*, *Montreal.*

N.B.—Names of deceased members are in *italics.*

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The Canadian Society of Civil Engineers.

Established February 24th, 1887—Incorporated by Dominion Act June 23rd, 1887, 50 Vic., Cap. 124.

1905.

PRESIDENT

ERNEST MARCEAU.

VICE-PRESIDENTS

C. H. KEEFER, D. MACPHERSON,
G. A. MOUNTAIN.

TREASURER

H. IRWIN.

SECRETARY

CLEMENT H. MCLEOD.

PAST PRESIDENTS

Holding a Seat on the Council.

M. MURPHY, K. W. BLACKWELL,
W. P. ANDERSON.

COUNCILLORS

H. C. BURCHELL,
M. J. BUTLER,
G. J. DESBARATS,
A. E. DOUCET,
R. J. DURLEY,
P. JOHNSON,
J. KENNEDY,
G. A. KEEFER,
R. W. LEONARD.
W. B. MACKENZIE,
R. B. OWENS,
J. B. PORTER,
C. H. RUST,
P. W. ST. GEORGE,
W. F. TYE.

LIBRARIAN

H. R. LORDLY.

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STANDING COMMITTEES

ON FINANCE.

D. MacPherson, *Chairman*,
H. Irwin,
K. W. Blackwell,
G. A. Mountain,
W. F. Tye.

ON LIBRARY.

J. B. Porter, *Chairman*,
R. J. Durley,
H. R. Lordly,
C. H. McLeod,
P. Johnson.

SPECIAL COMMITTEES

(ON GZOWSKI MEDAL).

J. G. Desbarats, *Chairman*.

M. J. Butler,
J. Galbraith,
C. H. Keefer,
R. B. Rogers,
R. B. Owens,
R. W. Leonard.

OFFICERS OF SECTIONS

General:	P. Johnson, *President*,
	C. H. Rust, *Vice-President*.
Electrical:	R. B. Owens, *President*,
	M. J. Butler, *Vice-President*.
Mechanical:	R. J. Durley, *President*,
	G. J. Desbarats, *Vice-President*.
Mining:	J. B. Porter, *President*,
	H. C. Burchell, *Vice-President*.

STATEMENT OF MEMBERSHIP

	Jan. 30th, 1904.			Jan. 30th, 1905.		
	Res.	Non-Res.	Total.	Res.	Non-Res.	Total
Honorary Members.. ..	2	8	10	1	9	10
Members.	72	306	378	63	321	384
Associate Members . ..	97	265	362	93	285	378
Associates..	16	19	35	18	18	36
Students	111	249	360	150	286	436
Total			1,145			1,244

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CANADIAN SOCIETY OF CIVIL ENGINEERS.

List of Officers and Members of Council since the establishment of the Society, showing the years during which office has been held.

PRESIDENTS.

ANDERSON, W. P.....1904.
BLACKWELL, K. W....1903.
BOVEY, H. T.....1900.
GZOWSKI, C. S.....1889, 1890, 1891.
HANNAFORD, E. P.....1893.
JENNINGS, W. T.....1899.
KEATING, E. H.....1901.
KEEFER, S.....1888.
KEEFER, T. C.....1887, 1897.
KENNEDY, JOHN.....1892.
MARCEAU, ERNEST.. .1905.
MONRO, THOS.....1895.
MURPHY, MARTIN.....1902.
PETERSON, P. A.....1894.
THOMPSON, W. G.....1898.
WALLIS, H.....1896.

VICE-PRESIDENTS.

ANDERSON, W. P.....1902.
BLACKWELL, K. W....1898, 1899, 1902,
BOVEY, H. T.....1896, 1897.
DODWELL, C. E. W... 1904.
DUGGAN, G. H.....1897, 1900, 1901, 1902, 1903.
GZOWSKI, C. S.....1887, 1888.
HANNAFORD, E. P.....1888, 1889, 1890, 1891.
JENNINGS, W. T.....1892, 1893, 1895, 1897.
KEATING, E. H.....1899, 1900.
KEEFER, C. H.....1904, 1905.
KENNEDY, JOHN.....1887, 1890, 1891.
LUMSDEN, H. D.....1898.
LYNCH, F. J.....1891.
MACDONALD, CHAS....1896.
MACDOUGALL, A.....1894.
MACPHERSON, DUNCAN.1905.
MARCEAU, E.....1901, 1902, 1903. 1904.
MONRO, THOS.....1892, 1893.
MOUNTAIN, G. A.....1903, 1905.
MURPHY, M.....1895.
PERLEY, H. F.....1888, 1889, 1890.
PETERSON, P. A.....1889, 1892, 1893.
RUST, C. H.....1901.
SHANLY, W.....1887.
ST. GEORGE, P. W....1894, 1898, 1899, 1900
THOMPSON, W. G ....1896, 1897.
WALLIS, H.....1893, 1895.

COUNCILLORS.

ABBOTT, H.....1888, 1894.
ANDERSON, W. P.....1890, 1891, 1901.
ARCHIBALD, P. S.....1894, 1895, 1901.
BAILLAIRGÉ, C. P.....1892.
BAILLAIRGÉ, G. F.....1881.
BARCLAY, W. D .....1896.
BARNETT, J. D.....1889, 1890, 1891, 1892, 1893, 1894, 1895, 1896, 1898.
BLACKWELL, K. W....1889, 1890, 1891, 1892.
BOSWELL, ST. GEO. J..1889, 1896, 1897, 1898, 1899, 1900, 1903, 1904.
BOVEY, H. T.....1892, 1893, 1894, 1895.
BROWN, F. R. F.....1888, 1889, 1890, 1891, 1893.
BUTLER, M. J.....1896, 1897, 1904. 1905.
BUTLER, W. R.....1896, 1901, 1902, 1903, 1904.
BURCHELL, H. C.....1905.
CAMBIE, H. J.....1892, 1896, 1901, 1904.
CHANUTE, O.....1894.
CHIPMAN, W.....1899, 1901, 1902.
COSTE, J. L. N.....1898.
CUNINGHAM, G. C.....1889, 1893, 1894, 1895, 1896, 1897.
DAWSON, W. B.....1896.
DESBARATS, G. J.....1905.
DODWELL, C. E. W...1890, 1891, 1892, 1895, 1897, 1898, 1899, 1900, 1903.
DOMVILLE, C. K.....1893.
DONKIN, H. ... .1891, 1894.
DOUCET, A. E.....1905.
DUGGAN, G. H.....1894, 1896, 1898, 1899, 1904.
DURLEY, R. J.....1905.
GALBRAITH, J.....1894, 1895, 1898, 1899, 1900, 1903.
GAMBLE, F. C.....1892, 1898.
GARDEN, G. H.....1894.
GILPIN, E.....1889.
GISBORNE, F. N.....1887, 1888, 1889, 1891, 1892.

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HANNAFORD, E. P....1887.
HASKINS, WM .....1894.
HOARE, E. A.....1891, 1892, 1902,
HOBSON, J..... ...1888, 1891, 1892,
HERING, R.....1900, 1901.
HOWARD, S.....1899, 1902, 1903
IRWIN, H ....1896, 1897.
JENNINGS. W. T.....1887, 1888, 1889, 1890, 1891.
JOHNSON, PHELPS .. .1904, 1905.
JOHNSON, E. V.....1902.
KEATING, E. H.....1896, 1897, 1898.
KEEFER, C. H.....1892, 1893, 1903.
KEEFER, G. A.....1889, 1890, 1897. 1905.
KEEFER, S.....1887.
KEELEY, D. H.....1887.
KENNEDY, JOHN.....1888, 1889, 1899, 1900, 1901, 1902, 1903, 1904, 1905.
KER, N. J..... 02.
KETCHUM, H. G. C...1890, 1892.
LEONARD, R. W.....1905.
LESAGE, L.....1887, 1888.
LUMSDEN, H. D.....1887, 1892, 1893, 1895.
MACDOUGALL, A..... 17, 1888, 1892, 1893, 1896, 1897.
MACKENZIE, W. B.....1899, 1902, 1903, 1904, 1905.
MACLEOD, H. A. F....1888, 1894.
MACPHERSON, D.....1895, 1897, 1898, 1899, 1900, 1901, 1903, 1904.
MARCEAU, E.....1897, 1898, 1899, 1900.
MASSY, G. H.... ....1890.
MATHESON, W. G....1896, 1902.
MOHUN, E.....1893, 1903.
MONRO, THOS.....1890, 1891, 1899, 1900.
MOUNTAIN, G. A.....1893, 1899, 1900, 1901.
MURPHY, M.....1888, 1889, 1897.
MCCARTHY, J. M.....1900, 1902.
MCCONNELL, B. D....1889, 1901.
MCHENRY, E. H.....1904.
MCNAB, W.....1900.
OWENS, R. B.....1904, 1905.
PERLEY, H. F.....1887.
PETERS, H..... 1887, 1894, 1897, 1898.
PETERSON, P. A.....1887, 1888, 1890, 1891.
POOLE, H. S.....1887, 1888, 1893, 1900.
PORTER, J. B.....1904, 1905.
REDPATH, F. R.....1890.
RIDOUT, THOS.....1893.
ROGERS, R. B.....1901, 1902, 1903, 1904.
ROSS, JAMES.....1900, 1901.
ROSS, R. A.....1902, 1903.
RUST, C. H.....1897, 1899, 1900 1905.
RUTTAN, H. N.....1887, 1888, 1890, 1891, 1892, 1894, 1895, 1897, 1898, 1899, 1902.
SCHREIBER, C..... ....1887, 1888.
SHANLY, J M.....1895, 1898.
SMITH, C. B.....1898, 1901, 1902, 1903, 1904.
SMITH, H. B.....1895.
SPROULE, W. J.....1895, 1896, 1897.
STEWART, D. A.....1896.
ST. GEORGE, P. W....1897, 1888, 1890, 1891, 1892, 1893, 1904, 1905.
SURTEES, R.....1895.
THOMPSON, W. G.....1895.
TRUTCH, J. W., SIR...1890, 1891.
TRACY, T. H.....1900.
TYE, W. F..... ....1905.
VALLÉE, L. A..... .1894, 1895, 1903.
VANIER, J. E.....1889.
WALBANK, W. MCL...1898, 1903, 1904.
WALLIS, H.....1887, 1900.
WILMOT, E. A.....1899.
WRAGGE, E.....1889, 1890.

TREASURERS.

BLACKWELL, K. W....1894, 1895, 1896, 1897.
IRWIN, H.....1898, 1899, 1900, 1901, 1902, 1903, 1904.
WALLIS, H.....1888, 1889, 1890, 1891, 1892, 1893.

SECRETARIES.

BOVEY, H. T.....1887, 1888, 1889, 1890, 1891.
MCLEOD, C. H.....1891, 1892, 1893, 1894, 1895, 1896, 1897, 1898, 1899, 1900, 1901, 1902, 1903, 1904, 1905.

LIBRARIANS.

CAPE, E. G. M.....1903, 1904.
CHADWICK, F.....1888, 1889, 1890, 1891.
LORDLY, H. R.....1905.
MCNAB, W.....1891, 1892, 1893, 1894, 1895, 1896, 1897, 1898, 1899.
RHYS-ROBERTS, E. A..1900, 1901, 1902.

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HONORARY MEMBERS.

(Hon. M. Can. Soc. C.E.)

Date of Membership.	*Name.*	*Address.*
1894 Jan. 4.	ABERDEEN, The Right Hon., the Earl of, P.C., LL.D.	Aberdeen, Scotland.
1889 May 23.	BRAMWELL, *Sir* FREDERICK JOSEPH, D.C.L., F.R.S.	5 Great George St., London, England.
1889 Jan. 3.	*Dawson, Sir John William.*	
1889 Jan. 3.	DERBY, The Right Hon. the Earl of, G.C.B.	Knowsley, Liverpool, England.
1889 Nov. 14.	*Fowler, Sir John.*	
1903 Oct. 8.	GIROUARD, *Lt.-Col. Sir* Percy C.	Johannesburg, South Africa.
1889 Mar. 28.	HARTLEY, *Sir* CHARLES AUGUSTUS, K.C.M.G.	26 Pall Mall, London, S.W., England.
1889 Nov. 14.	*Hawkshaw, Sir John.*	
1903 Oct. 8.	KEEFER, Thomas C., C.M.G.	Ottawa, Ont.
1889 May 23.	KELVIN, The Right Hon. Lord, F.R.SS.L. & E., LL.D.	The University, Glasgow, Scotland.
1896 Jan. 9.	MACDONALD, *Sir* W. C.	891 Sherbrooke St., Montreal.
1899 Nov. 23.	MINTO, The Right Hon. Earl of, G.C.M.G.	Ottawa, Ont.
1900 Apr. 26.	STRATHCONA AND MOUNT ROYAL, Lord, G.C.M.G.	1157 Dorchester St., Montreal.

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President. .

Vice-Presidents . . .

Councillors

Past Presidents . . .

Secretary

Treasurer

Librarian .

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MEMBERS.

(M. Can. Soc. C. E.)

In the following list (†) prefixed to a name indicates the contributor of a paper published in the Transactions of the Society; (G) prefixed to a name indicates the award of the Gzowski medal; (*q*) indicates admission under the special provisions of the Quebec Act.

Date of Membership.	*Name.*	*Address.*
1887 Feb. 3.	ABBOTT, HARRY	Vancouver, B.C.
1887 Jan. 20.	*Abbott, Job*	
1904 Jan. 14.	ABELL, HARRY C.	Denver Gas & Electric Co., Denver, Col.
1893 Apl. 20. S. 1899 May 25 A.M. 1904 Dec. 15. M.	ALISON, THOMAS H., C.E. *(Tor. Univ.)*	39 Cortlandt St., New York.
1887 Oct. 16. A.M. 1895 Feb. 28. M.	ALLISON, JOHN LOGIE	80 St. Francois Xavier St., Montreal.
1903 Oct. 8.	ANDERSON, GEORGE G.	Nor. West Irrig. Co., Lethbridge, Alta.
1887 Jan. 20.	†ANDERSON, WM. P., *Lt.-Col.* *(Past President.)*	Dept. of Marine, Ottawa.
1902 Dec. 18.	ANTHONY, FRANK D.	Goderich, Ont.
1887 Nov. 11.	ARCHIBALD, PETER S.	Moncton, N.B.
1887 Jan. 20.	ARMOUR, ROBERT	Asst. Eng. G.T.R., Montreal.
1887 Jan. 20.	ARMSTRONG, HARRY W. D.	Lindsay, Ont.
1888 Oct. 11.	ARMSTRONG, JOHN HARVEY	Box 7, St. Catharines, Ont.
1887 Jan. 20.	†ARMSTRONG, J. S.	Rothesay, N.B.
1887 Feb. 24.	AYLEN, JOHN	Aylmer, P.Q.
1887 Jan. 20.	AYLMER, JOHN A.	Gamebridge, Ont.
1887 Feb. 3.	†BAILLAIRGÉ, CHARLES P., F.R.S.C.	Quebec.
1887 Feb. 3.	BAILLAIRGÉ, GEORGE FRED.	318 St. Louis Rd., Notre Dame de Quebec.
1903 Apr. 23.	BAINBRIDGE, ROBERT ARTHUR.	Nelson, B.C.
1888 Jan. 27.	BAKER, *Sir* BENJAMIN	2 Queen Sq. Pl., London, S.W., England.
1887 Jan. 20.	BARBER, JAMES HENRY	C.P.R., St. John, N.B.
1904 Dec. 15.	BARBOUR, FRANK A.	1120 Tremont Bdg., Boston, Mass.
1889 Nov. 14.	BARCLAY, WILLIAM DUNCAN	486 Portland Ave., St. Paul, Minn.
1887 Feb. 3.	BARLOW, JOHN RIGNEY	City Hall, Montreal.
1887 Jan. 20.	†BARNETT, JOHN DAVIS	Stratford, Ont.
1893 May. 18.	BARROW, ERNEST GEORGE	City Hall, Hamilton, Ont.
1892 Mar. 11	BARRY, AUG. BURGES	702 Spadina Ave., Toronto.

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1887 Feb. 3.		BARTLETT, JAMES HERBERT	Middlesborough, Kentucky.
1887 Mar. 12.		BAYNE, GEORGE ARTHUR	114 Garry St., Winnipeg, Man.
1887 Jan. 20.		BEAUDRY, JOS, A. U	107 St. James St., Montreal.
1887 Feb. 3.		BEEVOR, ABRAHAM FRED	G.T.R., Montreal.
1898 Mar. 8.	A.M.	BELANGER, E	City Hall, Montreal.
1902 May 22.	M.		
1887 Feb. 3.		BELCHER, JOHN E	Peterborough, Ont.
1899 Jan. 5.		BELKNAP, S. F. (*q*)	C.P.R., Farnham, Que.
1902 May 22.		BELL, ANDREW, B.A. *(Queens)*	Almonte, Ont.
1887 Sept. 17.		BELL, JAMES ANTHONY	St. Thomas, Ont.
1897 May 20.	A.M.	BERLINGUET, F. X (*q*)	209 St. John St., Quebec.
1899 Jan. 31.	M.		
1887 Feb. 24.	A.M.	BERLINGUET, F. X. T	Grand'Mere, Que.
1890 Nov. 20.	M.		
1897 Dec. 9.		BERNASCONI, GUSTAVUS A	Antigonish, N.S.
1887 Feb. 3.		BERRYMAN, EDGAR	10 Baile St., Montreal.
1888 Dec. 6.	S.	BICKERDIKE, ROBT., JR.,	
1895 May 23.	A.M.	M.A.E	Dept. Marine, Ottawa.
1900 Nov. 22.	M.		
1887 Feb. 3.		†BLACKWELL, KENNET WM	856 Sherbrooke St., Montreal.
		(Past President and Honorary Councillor.)	
1887 Feb. 3.		*Boag, Robert*	
1887 Feb 3.		*Bolland, Percy James Lees*	
1887 May 23.		BONZANO, ADOLPHUS	331 South 18th St., Philadelphia, Pa.
1887 Jan. 20.		†BOSWELL, ST. GEO. J., B.A. Sc.	24 Anne St., Quebec.
1888 Apr. 19.	A.M.	BOWMAN, HERBERT JOSEPH,	
1896 Dec. 17.	M.	*Grad. S.P. Sc*	Berlin, Ont.
1899 Oct. 12.		BOURCHIER, GEORGE LOUGH	Address wanted.
1887 Jan. 20.		G† BOVEY, HENRY TAYLOR, D.C.L., LL.D., F.R.S.C., *(Past President.)*	McGill University, Montreal.
1887 June 25.		BREEN, THOMAS	P. O. Box 327, Quebec.
1903 Apr. 23.		BREITHAUPT, WILLIAM HENRY	Berlin, Ont.
1887 Jan. 20.		BRITTAIN, ALFRED	City Hall, Montreal.
1887 Apr. 28.	S.	BROOKS, NOEL E	C. P. Ry. Calgary, N.W.T.
1890 Nov. 20.	A.M.		
1897 Dec. 9.	M.		
1890 May 22.	A.M.	†BROUGH, WALTER C	Goderich, Ont.
1893 Apr. 20.	M.		
1887 Feb. 3.		BROWN, FRANCIS R. F	Address wanted.
1897 May 6.	A. M.	BRUCE, A. H. N	75 Somerset St., Ottawa.
1901 Nov. 21.	M.		
1899 May 25	A.M.	BRUCE, ROBERT F. H.	Can. At. Ry., Ottawa.
1904 Jan. 14.	M		

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1887 Feb. 3.		BRUSH, GEORGE	Eagle Foundry, Montreal.
1897 May 6.		BUCK, LIONEL HARTLEY	Revelstoke, B.C.
1903 May 21.		BUCK, RICHARD S.	Dept. of Bridges, Park Row Bdg., New York.
1887 June 9.		†BURCHELL, HERBERT CHAS. *(Member of Council.)*	St. John's, Nfld.
1903 Apr. 23.		BURKE, JOHN WILLIAM	45 Broadway, New York.
1890 Feb. 27.	A.M.	BURNS, WILLIAM	Can. N. Ry., Prince Albert, Sask.
1902 Oct. 9.	M.		
1894 Dec. 20.		BURNYEAT, JOHN P.	Vernon, B.C.
1890 Feb. 27.		BURPEE, MOSES	Box 450, Houlton, Me.
1901 Apr. 25.		G†BUSH, HARRY DEAN	Baltimore Bridge Co., Baltimore, Md.
1887 Jan. 20.		†BUTLER, MATTHEW JOS. *(Member of Council.)*	Asst. Chief Engineer, Trans-Cont. Ry., Ottawa.
1887 Jan. 20.		BUTLER, WILLIAM ROBT., MA.E.	R. M. Coll., Kingston, Ont.
1889 Jan. 3.		CADDY, JOHN ST. VINCENT	327 Theodore St., Ottawa, Ont.
1888 Feb. 9.		†CAMBIE, HENRY JOHN	Vancouver, B.C.
1887 Feb. 24.		CAME, FRANK ELDON	Lachine, P.Q.
1888 Mar. 22.	A.M.	†CAMPBELL, ARCH. WM.	Dept. Pub. Works, Toronto, Ont.
1896 June 18.	M.		
1903 May 21.		CARMAN, GUY C.	Iroquois, Ont.
1887 Jan. 20.		CARRE HENRY	Box 203, Belleville, Ont.
1894 Mar. 29.		†CARROLL, CYRUS	Prince Albert, N.W.T.
1887 June 27.		CARRY, HENRY E. C.	Box 574, Vancouver, B.C.
1899 Mar. 16.		†CARTWRIGHT, CONWAY EDW.	Vancouver, B.C.
1890 May 22		CHANUTE, OCTAVE	413 East Huron St., Chicago.
1904 Jan. 14.		CHAMBERS, ROBERT E., B.A.	Wabana, Nfld.
1887 Feb. 24.		CHAPMAN, CHAS. HERBERT	Anglo-American Club, Apartado No. 423, Mexico.
1889 Nov. 14.	A.M.	CHAPMAN, WALTER PECK	G.T.R., Hamilton, Ont.
1903 May 21.	M.		
1901 Nov. 21.		CHILD, J. T.	Irrigation Office, Calgary, N.W.T.
1887 June 9.		†CHIPMAN, WILLIS, B.A. Sc.	103 Bay St., Toronto, Ont.
1887 Feb. 24.	S.	CLEMENT, WILLIAM ALEX., *Grad. S.P. Sc.*	City Engineer's Off., Toronto.
1899 Oct. 12.	A.M.		
1902 Oct. 9.	M.		
1899 Dec. 21.		COBURN, CHARLES NEWLANDS	C. P. Ry., Montreal.
1899 May 25.		COFFIN, FREEMAN CLARK	53 State St., Boston, Mass.
1888 Apr. 19.		*Cooke, Richard Plunkett*	
1890 Nov. 20.		†CORTHELL, ELMER LAWRENCE	1 Nassau St., New York.
1887 Jan. 20.		COSTE, JEAN LOUIS NAPOLEON	Dept. Public Works, Ottawa.

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1888 Mar. 25. 1894 Dec. 20. 1901 Apr. 25.	S. A.M. M.	†COUTLEE, C. R.	Box 1069, Ottawa.
1887 Nov. 11. 1898 May 19.	A.M. M.	COWIE, FREDERIC WM.....	Dept. Marine, Ottawa.
1887 Jan. 20.		CRAWFORD, WILLIAM.....	Box 345, Ottawa.
1904 Dec. 15.		CREELMAN, FRANK, B.Sc.....	The Russell, Ottawa.
1904 Dec. 15.		CROFTS, J. C. T.	399 Carlton St., Toronto.
1887 Feb. 24. 1899 May 25.	A.M. M.	CROWLEY, CHARLES JAMES....	North River Tunnel Pennsylvania R. R., 234 W. 21st. St., New York.
1887 Feb. 3.		†CUNINGHAM, GRANVILLE C...	37 Craven Hill Gardens, London, England.
1888 Jan. 6.		CUSHING, RICHMOND HERSEY..	St. John, N.B.
1888 Mar. 22.		DANCER, CHAS. HENRY.....	184 Fort St., Winnipeg, Man.
1904 May 10.		DARLING, F. S. (*q*)	C. P. Ry., Toronto, Ont.
1896. Dec. 17. 1901 Jan. 17.	A.M. M.	DAVIS, ALLAN ROSS, B.A.Sc..	Molson's Bank Bdg., Winnipeg, Man.
1900 Apr. 12.		DAVIS, CHAS. HENRY.....	South Yarmouth, Mass.
1887 Feb. 24. 1891 Apr. 9	A.M. M.	DAVIS, WILLIAM MAHLON.....	Berlin, Ont.
1887 Jan. 20.		†DAVY, RICHARD ADAMS.....	Gamebridge, Ont.
1887 Feb. 24.		†DAWSON, WM. BELL, MA. E., M.A., D.Sc., F.R.S.C.....	Engineer in charge of Tidal Survey, Dept. of Marine, Ottawa.
1898 Nov. 8.		DEDMAN, ALFRED (*q*).....	214 St. James St., Montreal.
1897 May 20.		*DeGurse, Jos*.....	
1901 Nov. 21.		DENNIS, A. C.....	C/o C. P. Ry. Construction Dept., Montreal.
1901 Nov. 21.		DENNIS, J. S.....	Assist. to 2nd. V.P., C.P. Ry., Calgary, Alta.
1897 May 20.		DESBARATS, GEORGE J. ... *(Member of Council.)*	Sorel, Que.
1887 Jan. 6.		DICKEY, JAMES ALEX.....	Amherst, N.S.
1901 Apr. 25.		DION, A. A.....	Ottawa Elec. Co., Ottawa.
1887 Apr. 12. 1889 Jan. 3. 1892 Apr. 8.	S. A.M. M.	DOANE, FRANCIS W. W.....	City Engineer, Halifax, N.S.
1887 Jan. 20.		†DODWELL, CHARLES E. W.,	46 Cobourg Rd., Halifax, N.S.
1889 Feb. 14.		DONALDSON, MORLEY.....	Can. Atlantic Ry., Ottawa.
1887 June 9.		DONKIN, HIRAM.....	North Sydney, C.B.
1887 June 9.		DOUCET, CAPT. ARTHUR EMILE .. .. *(Member of Council.)*	Q. & L. St. J. Ry., Quebec.
1887 Feb. 24.		DRURY, EDMUND H.....	Sherbrooke, P.Q.
1895 May 23.		*Duchesnay, Edmund J*.....	

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1887 Feb. 24. A.M. 1887 Apr. 14. M.	DUFFY, AMBROSE	272 Somerset St., Ottawa.
1888 Mar. 22. A.M. 1890 Feb. 27. M.	DUGGAN, GEO. HERRICK, *Grad. S.P. Sc.*	Dominion Iron and Steel Co., Sydney, C.B.
1887 June 25. A.M. 1897 Dec. 9. M.	†DUNN, GUY C. B.	341 Lyon St., Ottawa.
1897 Mar. 11. A.M. 1904 Dec. 15. M.	†DURLEY, RICHARD JOHN *(Member of Council.)*	McGill University, Montreal.
1897 Mar. 11.	EARLE, WM. ZOBEISKI	St. John, N.B.
1894 Oct. 11.	EDINGTON, JOHN	Moncton, N.B.
1891 May 21. A.M. 1896 Dec. 17. M.	ELLIS, HENRY DISNEY	Commissioner Public Works, Kuching, Sarawak, Borneo.
1887 Feb. 24.	EVANS, JOHN DUNLOP	Trenton, Ont.
1887 Feb. 24.	EVANS, EDWARD ARTHUR	Quebec Railway, Light and Power Co., Quebec, P.Q.
1899 Feb. 14. A.M. 1902 Apr. 10. M.	FARLEY, RICHARD W *(q)*	Hull, P.Q.
1887 Jan. 20.	FELLOWES, G. R. L.	580 Lisgar St., Ottawa.
1900 May 31.	FERGIE, CHARLES	Westville, N.S.
1903 May 12.	FERGUSON, H. S. *(q)*	Millinocket, Maine.
1887 Feb. 3.	FIRTH, CHARLES	14 Holmlands Park, Sunderland, Eng.
1896 June 18.	FLEMING, *Sir* SANDFORD, C.M.G.	Ottawa.
1904 Jan. 14.	†FORREST, BENJAMIN J. B.A.	G. & G. Ry., Walton, Ont.
1889 Nov. 14.	FORREST, HORATIO FRED	Address wanted.
1887 Jan. 20.	*Forsyth, Robert*	
1888 Jan. 6. A.M. 1892 Dec. 28. M.	G† FORTIER, SAMUEL, PROF., B.A. Sc.	Box 92, Bozeman, Montana, U.S.
1902 Dec. 18.	FOSS, CHARLES ORRIN	Bridgewater, N.S.
1904 Nov. 17	FOWLER, CHAS. E.	95 Yesler Way, Seattle, Wash.
1887 Jan. 20.	FOWLER, ZACCHEUS JOHN	431 Gilmour St., Ottawa.
1887 Feb. 3.	*Franks, Cecil Bushe*	
1896 Mar. 12. A.M. 1902 Apr. 10. M.	FRANCIS, WALTER J., C.E. *(Tor. Univ.)*	Box 228, Peterborough, Ont.
1900 Apl. 12. A.M. 1904 Nov. 17 M.	FRASER, BASIL HALL	Dept. Marine, Ottawa.
1888 June 27.	FRY, HENRY	Chemainus, B.C.
1887 Jan. 20.	GALBRAITH, JOHN, PROF., M.A.	School of Practical Science, Toronto.
1888 Mar. 22	GALT, JOHN	Toronto.
1887 Jan. 20.	GAMBLE, F. C.	Dept. Land and Works, Victoria, B.C.

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1903 Apr. 23.	GARDEN, CHARLES	Woodstock, N.B.
1887 Jan. 20.	GARDEN, GEORGE HERBERT.....	St. Lambert, P.Q.
1894 Oct. 11.	GARDEN, JAMES F.....	Vancouver, B.C.
1903 Apr. 23.	GAUDET (*Major*), FREDERICK MONDELET.	Dominion Arsenal, Quebec, P.Q.
1887 Jan. 20.	GIBSON, PETER SILAS.....	Willowdale, Ont.
1887 Jan. 20.	*Gilbert, E. E.*	
1887 Jan. 20.	GILBERT FRANK.....	4160 Dorchester St., Westmount.
1887 Feb. 3.	*Gilbert, Walter W.*	
1887 Jan. 20.	†*Gisborne, Frederick, N*.....	
1887 June 9 A.M. 1892 Dec. 23. M.	GISBORNE, HARTLEY.....	Caragana Lodge, Ladysmith, Vancouver Ild., B.C.
1888 Mar. 22.	GOAD, CHARLES EDWARD.....	15 Wellington Street, W., Toronto.
1903 May 21.	GOLDMARK, HENRY..	C.P.Ry., Montreal.
1903 Oct. 8.	GOSSLER, P. G.	Messrs. J. G. White & Son, 43 Exchange Pl., New York.
1891 Oct. 8. A.M. 1901 Nov. 21. M.	GRANT, A. J.....	Port Colborne, Ont.
1887 Jan. 20.	GRAY, HENRY ALFRED.....	Rooms 68 and 69, Confederation Life Bdg., Toronto.
1892 Jan. 28. A.M. 1894 Oct. 11. M.	GRAYDON, A. ORMSBY.....	City Hall, London, Ont.
1896 Dec. 17.	GREENWOOD (*Lt.-Col.*), H. S...	Dist. Engr., I.M. Ry., Johannesburg, S.A.
1898 Feb. 17.	*Gregory, Chas. Currie*..	
1901 Apr. 25.	GROSE, F. H.....	H.M. Dockyards, Chatham, England.
1887 Jan. 20.	*Guerin, Thomas*.....	
1902 Dec. 18.	GUTELIUS FRED'K. PASSMORE..	C.P. Ry., Montreal.
1887 Jan. 20.	*Gzowski, Col. Sir Casimir S.* ..	
1904 Jan. 14.	GWILLIM, JOHN COLE.....	Kingston, Ont.
1899 May 25.	HALL, RICHARD, B. Sc.....	Rat Portage, Ont.
1898 May 19.	HAMILTON, FREDERIC ADAM....	Dartmouth, N.S.
1887 Jan. 20.	*Hannaford, Edmund P*.....	
1902 Oct. 9.	HANEY, MICHAEL J.....	Home Life Bdg., Toronto.
1902 Dec. 18.	HARDY, GEORGE F.....	309 Broadway, New York.
1887 Feb. 24.	†HARKOM, JOHN WILLIAM.....	Can. Foundry Co., Toronto.
1887 Jan. 20.	*Harrington, T. W.*	
1888 Feb. 9.	HARRIS, WILLIAM DALE.....	263 McLaren St., Ottawa.
1891 Jan. 29.	*Haskins, William*.....	
1901 Apr. 25.	HAULTAIN, H. E. T., C.E. (*Tor. Univ.*)	Address wanted.

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1887 Feb. 24.	HAY, THOS. ALEX. STEWART...	Peterborough, Ont.
1903 Apr. 23.	HAZLEWOOD, RICHARD A.	Port Arthur, Ont.
1903 May 21.	HEDRICK, IRA G..	2216 East 8th Street, Kansas City, Mo.
1888 May 17.	HEGAN, JAMES BLACK.....	Dept. Public Wks., Charlottetown, P.E.I.
1887 Jan. 20.	HENDERSON, ERNEST G.....	Windsor, Ont.
1887 Jan. 20.	†*Henshaw, George H*.....	
1889 May 23.	HERING, RUDOLPH.....	170 Broadway, New York.
1888 May 17.	HERTZBERG, ANTON LUND.....	C.P. Ry., Toronto.
1888 May 17.	HIBBARD, FRANK A.....	Trans-Cont. Ry., Quebec.
1887 Feb. 3.	HILL, ALBERT JAMES, M.A.....	New Westminster, B.C.
1887 June 25.	HILL, ARTHUR ED. BRETON, B.A.Sc.	New Westminster, B.C.
1887 Jan. 20.	HILLMAN, THOMAS EDWARD....	Prov. & Loan Bdg., Hamilton, Ont.
1889 Feb. 14. A.M. 1894 Oct. 11. M.	*Hislop, John*.....	
1887 Jan. 20.	HOARE, EDWARD ARTHUR.....	Chief Engineer, Quebec Bridge Co., Quebec.
1887 Jan. 20.	HOBSON, JOSEPH.....	G.T. Ry., Montreal.
1887 Feb. 2 A.M. 1904 Nov. 17. M.	HODGINS (*Major*), A.E.....	Dist. Engr., Trans-Cont. Ry., Com., Winnipeg, Man.
1887 Dec. 1.	HOLGATE, HENRY.....	Nor. Brit. & Mer. Ins. Bdg., Montreal.
1887 Jan. 20.	HOLLAND, GEORGE.....	P. O. Box 529, Montreal.
1889 Feb. 14. A.M. 1889 Dec. 19 M.	HOLT, HERBERT SAMUEL.....	297 Stanley St., Montreal.
1887 Jan. 20. S. 1891 Apr. 9. A.M. 1901 Nov. 21 M.	†HOPKINS, MARSHALL W.	C/o Surveyor Genl., Ottawa.
1887 Jan. 20.	G†HOWARD, STUART.....	City Hall, Montreal.
1887 Jan. 20.	*Hyndman, Patrick Kennedy*.....	
1887 Jan. 20. A.M. 1892 May 20 M.	†IRWIN, HENRY ..... *(Treasurer and Member of Council.)*	72 Tupper St., Montreal.
1903 Oct. 8.	G†JAMIESON, JAMES A.	313 Bd. Trade Bdg., Montreal.
1887 Jan. 20.	JENNINGS, WILLIAM T..... *(Past President.)*	Molson's Bank Bdg., Corner King & Bay Sts., Toronto.
1887 Feb. 24.	JOHNSON, E. V.....	Dept. of Railways, Ottawa.
1893 Apr. 20.	JOHNSON, PHELPS.. .. .. .. *(Member of Council.)*	Dom. Bridge Co., Montreal.
1893 Apr. 12.	JOHNSON, WM. A.....	134 King St. W., Toronto.
1901 Apr. 25.	JOHNSON, WALLACE C.....	Bk. Ottawa Bdg., Montreal.
1892 Dec. 23. A.M. 1897 Mar. 11. M.	JONES, THOS. H., B.A. Sc.	Brantford, Ont.

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1895 May 23.		†KEATING, EDWARD HENRY .. .. *(Past President.)*	Street Ry. Co., Toronto.
1887 Jan. 20.		KEEFER, CHAS. HENRY.... *(Vice-President.)*	Metropolitan Life Building, Ottawa.
1887 Feb 3.		KEEFER, GEORGE ALEX .. *(Member of Council.)*	Dept. Public Works, New Westminster, B.C.
1887 Feb 3.		†*Keefer, Harold*.....	
1887 Jan. 20.		†*Keefer, Samuel*.....	
1898 Nov. 8.		†KELSCH, R. S. (*q*)	4093 Tupper St., Westmount, Que.
1893 Apr. 20.		KENNEDY, JAMES CRON	Box 710, Owen Sound, Ont.
1887 Jan. 20. 1893 May 18.	A.M. M.	†KENNEDY, JAMES HENRY, C.E. *(Tor. Univ.)*	Grand Forks, B.C.
1887 Jan. 20.		†KENNEDY, JOHN ..... *(Past President and Member of Council.)*	Harbour Office, Montreal.
1887 Feb. 24.		KENNEDY, WILLIAM, JUN.....	Room 3, Y.M.C.A. Building, Montreal.
1888 Apr. 19. 1898. Dec. 8.	A.M. M.	KENRICK, ROBERT B.....	Dom. Bridge Co., Montreal.
1888 Mar. 22. 1894 Jan. 4. 1904 Apl. 14.	S. A.M. M.	†KERRY, JOHN G. G.	447 St. Urbain St., Montreal.
1887 Oct. 16.		o†*Ketchum, Henry Geo. Clopper*	
1887 Jan. 20.		†*Killaly, Hamilton H*.....	
1887 Jan. 20.		*Kingsford, William*.....	
1890 Nov. 20. 1896 Jan. 9. 1903 May 21.	S. A.M. M.	†KINGSTON, CHARLES B.	Worcester House, Walbrook, London, E.C., Eng.
1888 Mar. 22. 1896 Jan. 9.	A.M. M.	KIRKPATRICK, ALEX. KING.....	Kingston, Ont.
1887 Jan. 20.		LAFLEUR, EUGENE D.....	Dept. Pub. Works, Ottawa.
1887 Feb. 24. 1888 Nov. 14.	A.M. M.	LANTIER, ELZEAR.....	61 St. Louis St., Quebec.
1892 Dec. 23.		LANGTON, JOHN.....	99 John St., New York.
1887 Jan. 20.		†LAURIE, WALTER H.....	4 Montée du Zouave, Montreal.
1902 Dec. 18.	S.	LAWLOR, FRANCIS D. H.....	Burlington, Iowa.
1887 Jan. 20. 1894 Dec. 20. 1900 Apr. 12.	S. A.M. M.	o†LEA, RICHARD S., MA.E.....	851 Palace St., Montreal.
1887 Jan. 20.		LEDUC, DENIS.....	222 Grenado Bdg., Denver, Col.
1893 Oct. 12.		LEE, W. WALTER.....	Address wanted.
1903 Dec. 18.		LELUAU, CHARLES C.	874 St. Denis St., Montreal.
1887 Jan. 20. 1890 May 2.	A.M. M.	†LEONARD, REUBEN WELLS. .. .. *(Member of Council.)*	St. Catharines, Ont

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1904 Nov. 17.		†LEONARD, FRANCIS H., JR.	85 Inspector St., Montreal.
1887 Jan. 20.		*Lesage, Lewis*	
1887 Jan. 20.	A.M.	LESAGE, THOMAS W.,	
1899 Dec. 21.	M.	B.A. Sc.	City Hall, Montreal.
1889 Feb. 14.		LINDENTHAL, GUSTAV	45 Cedar St., New York.
1887 Jan. 20.		LUMSDEN, HUGH DAVID	Chief Engineer Trans-Continental Ry., Ottawa.
1887 May 12.		LYNCH, FRANCIS JOSEPH	Grenville, Quebec.
1881 June 9.	S.		
1891 Nov. 19.	A.M	LOCKE, ROBERT T.	Care of F. W. W. Doane, Halifax, N.S.
1903 Oct. 8.	M.		

1887 Jan. 20.	S.		
1890 Feb. 27.	A.M.	McCARTHY, JAMES M.	Jacques Cartier W. & P. Co., Quebec.
1897 May 6.	M.		
1888 Mar. 22.		McCARTHY, WILLIAM	120 Grande Allée, Quebec.
1887 Feb. 24	S.		
1890 Apr. 10.	A.M.	McCOLL, RODERICK	Prov. Engineer's Office, Halifax, N.S.
1896 Dec. 17.	M.		
1887 Jan. 20.		McCONNELL, BRIAN D.	Millbank, Ont.
1902 Dec. 18.		McHENRY, EDWIN H.	N. Y. N. H. & H. Ry., New Haven, Conn.
1903 Apr. 23.		McKAY, OWEN, *Grad. S.P. Sc.*	Walkerville, Ont.
1887 Jan. 20.		†McLEOD, PROF. C. H.,	
		F. R. S. C.	McGill University, Montreal.
		(Secretary and Member of Council.)	
1904 Nov. 17.		McMATH, FRANCIS C.	Walkerville, Ont.
1903 May 21.		McMILLAN, ALEX. J.	Address wanted.
1887 Jan. 20.		†McMINN, THOMAS JAMES	Asst. Sec. Am. Soc. C.E., 220 West 57th St., New York.
1887 Feb 3.		McNAB, WILLIAM	G.T.R., Montreal.
1887 Feb 3.		McWOOD, WILLIAM	G.T.R., Montreal.
1897 May 20.	A.M.	MacCUNN, JOHN	Res. Engineer, Niagara-Welland Power Co., St. Catharines, Ont.
1903 Oct. 8.	M.		
1898 Feb. 17.		MacDONALD, ARTHUR C.	Casilla 942, Valparaiso, Chili.
1889 Feb. 14.		MACDONALD, CHARLES	No. 1 Broadway, New York.
1896 June 18.		MACDONNELL, JOHN ALEX.	393 River Ave., Winnipeg. Man.
1887 Jan. 20.		†*Macdougall, Alan*	
1887 Nov. 11.		MACKENZIE, WM. BROUARD.	Moncton, N.B.
		(Member of Council.)	
1898 Dec. 8.		MACLENNAN, JOHN DONALD	Colorado Bdg., Washington, D.C.

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1887 Feb. 24.		MACKLIN, JOHN G.	20 Sun Life Bdg., Montreal.
1887 Jan. 20.		MACLEOD, HENRY A. F.	340 Cooper St., Ottawa.
1887 June 9.		MACLEOD, MALCOLM HUGH.	Chief Engr. Canadian Northern Railway, Winnipeg, Man.
1887 Jan. 20.		MACPHERSON, DUNCAN *(Vice-President.)*	C.P.R. Dalhousie Sq. Station, Montreal.
1900 May 31.	A.M.	MANN, WILLIAM E.	Box 68, Winnipeg, Man.
1902 Dec. 18.	M.		
1899 Oct. 12.		*Mahood, James A*	
1887 May 12.		G† MARCEAU, ERNEST *(President.)*	1709 Notre Dame St., Montreal.
1891 May 21.		MASSON, GEORGE	G.T.R., Detroit, Mich.
1887 Jan. 20.		†MASSY, GEORGE HUGH	4224 Dorchester St., Montreal.
1887 Feb. 3.		MATHESON, WILLIAM GRANT	New Glasgow, N.S.
1887 Dec. 1.	S.	MATTICE, E. S.	4278 Western Ave., Westmount.
1895 Dec. 19.	A.M.		
1902 Apr. 25.	M.		
1903 Oct. 8.		MAXWELL, DAVID F.	North Sydney, N.S.
1904 Jan. 14.		MERSHON, RALPH D.	St. Ry. Chambers, Montreal.
1902 Dec. 18.		METCALF, JOHN S.	804 The Temple, Chicago, Ill.
1887 June 9.		METCALFE, C. PERCIVAL	Sea Breeze, Netley Abbey, Eng.
1887 Feb. 24.		MILLER, FRED. FRASER, B.A.Sc.	Napanee, Ont.
1888 May 17.	A.M.	MILES, CHARLES LEBARON	Edmunston, N.B.
1890 Apr. 10.	M.		
1887 Nov. 11.		MILLIDGE, EDWIN GILPIN	Pub. Wks., Dept., Antigonish, N.S.
1895 Dec. 19.	A.M.	MILNE, JAMES	513 Huron St., Toronto.
1897 Dec. 9.	M.		
1898 Mar. 24.		MITCHELL, ALEXANDER	Cos Cob, Conn.
1894 Mar. 29.	S.	MITCHELL, CHARLES H., B.A.Sc., C.E. *(Tor. Univ.)*	Niagara Falls, Ont.
1898 Dec. 22.	A.M.		
1902 Apr. 10.	M.		
1903 May 21.		MOBERLY, FRANK	Victoria, B.C.
1887 Feb. 24.		MOFFAT, JAMES W., B.A. Sc.	Pioneer Mining Co., Slocan City, B.C.
1888 Feb. 9.		G†MOHUN, EDWARD	Union Club, Victoria, B.C.
1904 Dec. 15.		MOLESWORTH, ARTHUR N.	Trans-Cont. Ry., Ottawa.
1887 Jan. 20.		†*Monro, Thomas*	
1888 Mar. 22.		MORKILL, JOHN THOMAS	Sherbrooke, P.Q.
1887 Feb. 24	A.M.	†MORRIS, JAMES L., C.E. *(Tor. Univ.)*	Pembroke, Ont.
1904 Jan. 14.	M.		
1888 Mar. 22.		MORROW, HAROLD A.	Peterborough, Ont.
1894 Jan. 4.	A.M.		
1902 Apr. 10.	M.		
1887 Jan. 20.		†MOUNTAIN, G. ALPHONSO *(Vice-President.)*	Chief Engineer, Ry. Com. of Canada, Ottawa.

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1887 Feb 3.		†MURPHY, MARTIN, D.Sc....	247 Sussex Ave., Ottawa. *(Past President and Honorary Member of Council.)*
1901 Apr. 25.		MURDOCH, WILLIAM	St. John, N.B.
1904 Dec. 15.		NAISH *(Capt.)*, T. E.	Royal Engineers, Dublin, Ire.
1888 May 17.		NEILSON, MATTHEW.....	St. John Ry. Co., St. John, N.B.
1903 May 21.		ODELL, CHARLES M..	Glace Bay, C.B.
1895 Feb. 28.		O'DONNELL, JOHN PATRICK.....	Palace Chambers, Westminster, London, S.W., Eng.
1887 June 25 1895 May 23.	A.M. M.	O'DWYER, J. SEABURY, B.A. Sc.....	Intercolonial Ry., Moncton, N.B.
1887 Feb. 3. 1897 May 6.	A.M. M.	ORD, L. R.....	G.T.P.R. Surveys, Whitemouth, Man.
1887 Jan. 20.		O'ROURKE, JOHN FRANCIS.....	1 West 34th St., New York.
1887 May 12. 1892 Dec. 23.	A.M. M.	OSTLER, CHAS. HODGSON	Montreal Gas Co., Montreal.
1896 Dec. 17.		O'SULLIVAN, HENRY.....	Indian Lorette, P.Q.
1898 Dec. 22.		†OWENS, ROBERT BOWIE .. *(Member of Council.)*	McGill University, Montreal.
1887 May 12.		*Page, John*.....	
1887 Jan. 20.		PARENT, ETIENNE H.....	1030 St Denis St., Montreal.
1887 Jan. 20.		G†*Perley, Henry F*.....	
1888 Mar. 22.		*Perry, James Rudston*	
1887 Jan. 20.		†PETERSON, P. ALEX ..... *(Past-President.)*	Goderich, Ont.
1887 Jan. 20.		PETERS, HURD.....	St. John, N.B.
1894 Jan. 4. 1896 Jan. 9.	A.M. M.	PHILLIPS, ARTHUR TRISTRAM..	Box 355, Ottawa.
1888 May 19. 1903 Oct. 8.	A.M. M.	PILSWORTH, W. R.	Kamloops, B.C.
1887 Feb. 24.		PIM, JOSEPH PHELPS, B.A.....	G.T.R. Pacific Surveys, Winnipeg, Man.
1887 Jan. 20.		*Plunkett, Edmund Walter*.....	
1887 Jan. 20.		†POOLE, HENRY SKEFFINGTON..	162 Pleasant St., Halifax, N.S.
1896 Dec. 17.		PORTER, PROF. JOHN BONSALL, PH.D. ..... *(Member of Council.)*	McGill University, Montreal.
1889 Mar. 14.		POULIN, STANISLAS R.....	St. Alexandre, P.Q.
1887 June 25.		PRATT, ROBERT MURRAY.....	Box 216, Port Arthur, Ont.
1899 Jan. 4.		PRINGLE, ALEXANDER *(q)*.....	107 St. James St., Montreal.
1887 Feb. 24.		PRINGLE, THOMAS.....	Room 57, Imperial Bdg., Montreal.

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1902 Jan. 14.		RAINBOTH, G. C. (*q*)	Aylmer, Que.
1887 Oct. 6.		*Ramsey, William Allen*	
1887 Jan. 20.		RANNEY, GEORGE WARNER	Belleville, Ont.
1887 Jan. 20.		†RHEAUME, LOUIS NAPOLEON	Co|o Govt. Canals, Ottawa.
1887 Apr. 14.		RHODES, ARMITAGE	P.O. Box 212, Quebec.
1889 Dec. 19.	A.M.	RHYS-ROBERTS, EDMUND A	Dom. Bridge Co., Montreal.
1894 Oct. 11.	M.		
1887 Jan. 11.		RIDOUT, THOMAS	Dept. Rys. & Canals, Ottawa.
1887 Jan. 20.	A.M.	RIELLE, JOSEPH (*q*)	New York Life Building, Montreal.
1900 Oct. 9.	M.		
1894 Oct. 20.		ROBB, DAVID W	Amherst, N.S.
1887 Jan. 20.		†*Robertson, Geo. Edward*	
1901 Jan. 17.		G† ROBINSON ARTHUR WELLS	14 Phillips Sq., Montreal.
1887 May 12.		†ROGERS, RICHARD B., B.A.Sc.	Peterborough, Ont.
1887 Feb. 24.		*Rosamond, James Edward*	
1889 Feb. 14.	A.M.	ROSS, ALEXANDER BELL	No. 2 Calle de Gante, Mexico.
1897 Dec. 9.	M.		
1888 Oct. 11.		ROSS, JAMES	360 Peel St., Montreal.
1897 Mar. 11.	A.M.	ROSS, JOHN W. LEB	Morrisburg, Ont.
1901 Nov. 21.	M		
1897 May 6.		†ROSS, R. A., E.E. (*Tor. Univ.*)	Nor. Brit. & Mer. Ins. Bdg., Montreal.
1887 Feb. 3.		†RUST, CHARLES HENRY (*Member of Council.*)	City Hall, Toronto.
1888 Feb. 9.	S.	RUSSEL, WILLIAM B., *Grad. S.P. Sc.*	North Bay, Ont.
1899 May 25.	A.M.		
1903 Apr. 23.	M.		
1887 Jan. 20.		RUTTAN HY. NORLANDE	City Hall, Winnipeg.
1890 Feb. 28.	A.M.	SARGENT, CHAS. D	Cardinal, Ont.
1894 Jan. 4.	M.		
1891 Apr. 9.	A.M	SAUNDERS, B. JOHNSTON, B.A. Sc	Regina, N.W.T.
1899 Mar. 16.	M.		
1887 Feb. 24.		SCHREIBER, COLLINGWOOD, C.M.G.	Dept. of Railways, Ottawa.
1887 Feb. 24.	A.M.	SHANLY, JAMES MOORE	346 Prince Arthur Street, Montreal.
1890 Feb. 27.	M.		
1887 Feb. 24.		*Shanly, Walter*	
1892 Apl. 8.	A.M.	†SHEARWOOD, FRED PERRY	Dom. Bridge Co., Montreal.
1904 Nov. 17.	M.		
1887 Jan. 20.		SHEWEN, EDWARD T. P	Dept. Pub. Works, St. John, N.B.
1888 June 11.		SIEMENS, ALEXANDER	12 Queen Anne's Gate, London, England.
1902 Apr. 10.		SING, JOSIAH G	Engineers in charge Pub. Wks. Dept., London, Ont.

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1887 Feb. 24.		SIMPSON, FRANK	692 Spadina Ave., Toronto.
1903 Apr. 23.		*Simpson, George Albert*	
1887 Feb 3.		SMITH, A. H	346 St. James St., London, Ont.
1887 Dec. 1.	A.M.	†SMITH CECIL BRUNSWICK,	
1895 Dec. 19.	M.	MA.E	Niagara Falls, Ont.
1888 Feb. 9.		†SMITH, HENRY BADELEY	Box 284, Rossland, B.C.
1887 Jan. 20.		SMITH, HENRY	Dept. Crown Lands, Toronto.
1887 Sept. 17.		†*Smith, Thomas T. Vernon*	
1887 May 12.		SOMERVILLE, FRANK LINN	G.T. Ry., Toronto.
1902 Dec. 18.		SPELMAN, JAMES	804 The Temple, Chicago, Ill.
1894 Dec. 20.		SPENCE, JAS. BRUCE	Dept. Rys. & Canals, Ottawa.
1887 Jan. 20.		*Sproatt, C*	
1887 Jan. 20.		†SPROULE, WILLIAM JOHNSTON,	
		MA.E	Harbour Office, Montreal.
1903 May 21.		STADLY, G. W	Engr. Main of Way, Sault Ste. Marie, Ont.
1887 Feb. 24.	A.M.	†STECKEL, LOUIS JOSEPH RENE	Dept. Pub. Works, Ottawa.
1888 Feb. 9.	M.		
1903 May 21.		STEPHEN, ARTHUR B	Three Rivers, P.Q.
1890 Feb. 27.	S.		
1896 Mar. 12.	A.M.	STEVENS, ALFRED JAS	Temple Bdg., Toronto, Ont.
1900 Oct. 11.	M.		
1889 Nov. 14.		STEWART, ALEXANDER	435 Burke Bdg., Seattle, Wash.
1897 Dec. 9.		STEWART, ALEXANDER F	Dist. Engineer, Cape Govt. Rys., Kimberley, South Africa.
1893 Apr. 29.		†*Stewart, Donald Alexander*	
1888 Feb. 9.		STEWART, GEORGE ALEXANDER	Calgary, N.W.T.
1887 Feb. 24.		STEWART, ROBERT C	Bridgewater, N.S.
1904 Nov. 17.		STEWART, WILLIAM J.	Marine Dept. Ottawa.
1887 Jan. 20.		ST. GEORGE, PERCIVAL W. *(Member of Council.)*	2744 St. Catherine St., Montreal.
1891 Nov. 19.	A.M.	STOESS, CHAS. ANTHONY	29 Fairfield Block, Vancouver, B.C.
1892 Apr. 8.	M.		
1887 Jan. 20.		*Stokes, J. T*	
1900 Apr. 12.		SULLIVAN, JOHN G	C.P.Ry., Winnipeg, Man.
1887 Jan. 20.		SURTEES, ROBERT	333 McLaren St., Ottawa.
1888 June 11.		SUTCLIFFE, JOHN	171 Mansion Square, Poughkeepsie, N.Y.
1887 Feb. 24.		SYKES, SAMUEL H	78 Bismarck Ave., Toronto.
1887 Feb 3.		*Symmes, H. C*	
1890 Apr. 10.	A.M.	SYMMES, CHAS. THOMAS D	La Serena, Chili.
1896 June 18.	M.		

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1898 May 19. SZLAPKA, HENRY..... Narberth, Montgomery Co., Pa.

1903 Oct. 8. TACHE, JOSEPH C. .. .. Roberval, P.Q.
1887 Apr. 28. TATE, ROBERT FREDERICK.....294 Crawford St., Toronto.
1902 Apr. 10. †TAYLOR, JAMES J.....Box 540, New Glasgow, N.S.
1889 May 23. TEMPLE, EDMOND BONNER.....53 Murray St., Toronto.
1891 Jan. 29. *Thompson, Wm. Geo. McN.. ..*
1889 Dec. 19. THOMSON, FREDERICK.....774 Craig St., Montreal.
1887 Feb. 9. S. / 1894 Jan. 4. A.M. / 1900 May 31. M. } †THOMSON, W. CHASE.....Dom. Bridge Co., Montreal.
1888 Mar. 22. †*Torrance, John Fraser*.....
1900 Oct. 11. *Tower, Ashley B*.....
1888 Oct. 11. TRACY, *(Col.)*, THOMAS H.....City Hall, Vancouver, B.C.
1888 May 17 A.M. / 1897 May 6 M. } TRUE, ABBOTT.....Liverpool, N.S.
1896 Dec. 17. TYE, WM. FRANCIS ..... C.P.R., Montreal, P.Q. *(Member of Council.)*
1896 Dec. 17. TYRRELL, JAS. WILLIAMS, C.E. *(Tor. Univ.)* ..... 42 James St. N., Hamilton, Ont.
1899 Oct. 12. TYTLER, FREDERICK J. L.....1433 Nelson St., Vancouver,
1899 Dec. 21 A.M. / 1904 Dec. 15 M. } TOPP, CHARES H.B. .....City Engineer, Victoria, B.C.

1888 Jan. 6. *Unsworth, Joseph Lennon*.....

1892 Jan. 28. VALIQUET, ULRIC..... Dept. Public Works, Ottawa.
1887 Nov. 11. VALLEE, LOUIS ANDRE.....Dept. Public Works, Quebec.
1891 Apr. 9. A.M. / 1903 Apr. 23. M. } *Van Buskirk, Wm. Fraser* ....
1888 Jan. 9. G†VAUTELET, HENRI ETIENNE..69 Victoria St., Montreal.
1898 Feb. 17 A.M. / 1899 Dec. 21. M. } *Vindin, James Stanley*. .. .. ..

1903 May 21. WADDELL, JOHN A. L. .. .. ..New Nelson Bdg., Kansas City, Mo.
1887 Jan. 20. WALBANK, W. MCLEA, B.A.Sc. 214 Peel St., Montreal.
1900 Apl. 12 A.M. / 1904 Jan. 14. M. } WALKEM, HUGH BLAKE.. .....C.P. Ry., Vancouver, B.C.
1888 Apr. 19. A.M. / 1898 May 19. M. } WALKER, ALFRED P.....C.P.R. Union Stn., Toronto.

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1901 Nov. 21. A.M. 1902 Apr. 10. M.	WALLACE, JOSEPH H.	Temple Court Building, New York
1887 Jan. 20.	WALLIS, HERBERT. (*Past President.*)	239 Drummond St., Montreal.
1894 Dec. 20.	WALSH, EDMUND J.	236 Maria St., Ottawa.
1887 Jan. 20.	WANKLYN, FREDERICK LUMB.	112 St. Jas. St. Montreal.
1888 Oct. 11.	*Wasell, Edward*	
1898 Dec. 8.	WATSON, ALFRED DANIEL	8 Park Terrace, London Road, Portsmouth, England.
1899 May 25 A.M. 1904 Jan. 14. M.	WEATHERBE, *(Lt.-Col.)* PAUL.	Chief Engineer, Dept. Militia and Defence, Ottawa.
1887 Feb. 24.	†WEBSTER, GEO. HERBERT.	Divn. Engr. C. P. Ry., Vancouver, B.C.
1899 Oct. 12.	WELLER, JOHN LAING	St. Catharines, Ont.
1891 Oct 8.	*Wellington, Arthur M.*	
1898 May 19.	WEST, CHARLES W.	152 Windsor St., Halifax, N.S.
1893 May 18.	WETMORE, GEORGE LUDLOW	C.P. Ry., North Bay, Ont.
1896 Dec. 17.	†WHITE-FRASER, GEORGE	c/o Chief Astronomer, Ottawa.
1887 Jan. 20.	WHITE, THOS. HY.	Bridgewater, N.S.
1887 Jan. 20.	†WICKSTEED, HY. K., B.A. Sc.	Cobourg, Ont.
1894 Jan. 4. A.M. 1903 Apr. 23. M.	WILFORD, FREDERICK R.	St. Catharines, Ont.
1897 Mar. 11.	WILLIAMS, DAVID	St. Johnsbury, Vt.
1890 May 22.	WILLIAMS, JOHN	City Engr's. Off., Toronto.
1893 Apr. 20.	WILLIAMSON, FRANCIS STUART.	257 Broadway, New York.
1888 Jan. 6.	WILMOT, EDWARD ASHLEY.	Chilliwack, B.C.
1887 Feb. 24.	WILSON, JAMES	Supt. Q. V. Niagara Falls Park, Niagara Falls, Ont.
1887 Jan. 20.	*Wise, Frederick A.*	
1896 Dec. 17. A.M. 1897 May 6 M.	WOODMAN, JOHN	Winnipeg, Man.
1893 May 18 S. 1898 Mar. 24 A.M. 1901 Nov. 21. M.	WORSFOLD, C. C.	New Westminster, B.C.
1887 Jan. 20.	WRAGGE, EDMUND	115 Madison Ave., Toronto.
1899 May 25.	WRIGHT, JOHN JOSEPH	Toronto Electric Light Co., Toronto, Ont.
1889 Dec. 19.	*Yates, Henry*	
1889 Dec. 19.	ZURCHER, MAX A.	1211B St. Denis St. Montreal.

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ASSOCIATE MEMBERS.

(A. M. Can. Soc. C. E.)

Date of Membership.	*Name.*	*Address.*
1903 May 21.	ABBOTT, CHARLES A.	Nile Valley Co., Dakka, Upper Egypt.
1887 Jan. 20. S. 1898 Feb. 17. A.M.	ADDIE, GEO. KYLE.....	Sherbrooke, Que.
1899 Mar. 16. S. 1904 Nov. 17. A.M.	ALLAN, J. LORN, *Grad. S.P. Sc.*	15 Victoria Rd., Halifax, N.S.
1897 Mar. 11. S. 1904 Jan. 14. A.M.	ALEXANDER, RICHARD C. F....	C. P. Ry., Farnham, P.Q.
1899 Feb. 14.	AMIOT, P. E. (*q*).....	770 Berri St., Montreal.
1899 Jan. 4.	AMOS, ARTHUR (*q*).....	Corry Bdg., Ottawa.
1893 Apr. 20 S. 1897 May 20. A.M.	AMOS, EDOUARD CHARLES.....	Royal Insce. Bdg., Montreal.
1893 Apr. 20. S. 1896 June 18. A.M.	AMOS, LOUIS AUGUSTE.....	236 Temple Bdg., Montreal.
1898 Feb. 17. S. 1902 May 22. A.M.	†ANDERSON, WILLIAM B., B.A.Sc.	178 Cartier St., Ottawa.
1895 May 23. S. 1903 May 21. A.M.	ANGUS, WILLIAM F.	240 Drummond St., Montreal.
1890 May 22. S. 1899 Jan. 4. A.M.	ARCAND, O. (*q*).....	40 Notre Dame Street, Three Rivers, Que.
1888 May 17. S. 1901 Nov. 21. A.M.	ARCHIBALD, CYRUS W.....	I. C. Ry., Truro, N.S.
1887 Jan. 20.	*Archibald, Henry*	
1894 Oct. 11. S. 1902 Apr. 10. A.M.	ARMSTRONG, CHARLES J.	Resident Engr. Central S.A. Rys., Harrismith, Orange River Colony, S.A.
1903 May 21.	ARMSTRONG, JOHN, B.A. Sc. ..	Box 110, Edmonton, Alta.
1887 Feb. 24. S. 1892 Jan. 28. A.M.	†ASHBRIDGE, WELLINGTON T. C.E. *(Tor. Univ.)*	609 Temple Bldg., Toronto, Ont.
1904 Jan. 14.	†ASHCROFT, GLENN B., B.Sc..	607 Temple Bdg., Montreal.
1898 Oct. 11.	AUCLAIR, H. L. (*q*).....	City Hall, Montreal.
1887 June 25.	AYLMER, HARRY BROCK	Melbourne, P.Q.
1904 Jan. 14.	BADGER, HENRY S.	Bridgewater, N.S.
1892 Jan. 28.	BAKER, S. HARLAN	Cameron Block, Manistee, Mich.
1902 Apr. 10.	BAILLAIRGÉ, WILLIAM D....	City Hall, Quebec.
1899 Mar. 16. S. 1903 May 21. A.M.	BALFOUR, REGINALD H.	248 Mountain St., Montreal.
1899 Mar. 16. S. 1903 Apr. 23. A.M.	BALLOCH, GUY RALSTON	G. T. P. Surveys, Edmundston, N.B.
1904 Jan. 14.	BALSLEY, ABE, B.Sc.....	24 E. Alabama St., Atlanta, Ga.
1904 Nov. 17.	BARTLETT, ERNEST B.	Q. & L. St. J. Ry., Quebec.
1898 Nov. 8.	†BARTON, DONALD S. (*q*).....	40 Hospital St., Montreal.

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1901 Nov. 21.	BAYFIELD, H.A.	Molsons Bk. Bdg., Vancouver, B.C.
1904 Apl. 14.	BELL, CHARLES BURNBY	C. P. Ry., Montreal.
1899 May 20. S. 1904 Dec. 15. A.M.	BENNY, WALTER W.	C.P.Ry., Place Viger Stn., Montreal.
1897 May 20. S. 1896 Dec. 17. A.M.	BERTRAND, J. N. TETU	Fraserville, Quebec.
1898 Dec. 8.	BEULLAC, MARCEL C. J.	Dom. Bridge Co., Montreal.
1898 Mar. 24.	BIGGER, CHARLES A.	68 Daly Ave., Ottawa.
1896 Mar. 12. S. 1899 Jan. 4. A.M.	BISHOP, WILLIAM I. (*q*)	Supt. T. A. Gillespie Co., New London, N.C.
1894 Mar. 29. S. 1898 Dec. 22. A.M.	BLACK, JOHN D. (*q*)	New Can. Co., Paspebiac, P.Q.
1904 Jan. 14.	BLAIR, DAVID E.	111 Union Ave., Montreal.
1901 Apl. 25. S. 1904 Nov. 17. A.M.	BLANCHARD, A. C. D.	Can. Nia. Pr. Co., Niagara Falls, Ont.
1902 Apr. 10.	BOGART (*Capt.*), JOHN H. L.	Kingston, Ont.
1898 Mar. 24. S. 1902 Apr. 10. A.M.	BOND, F. LORNE	42 Union Ave., Montreal.
1897 Dec. 9. S. 1900 Oct. 11. A.M.	BOSWELL, ELIAS JOHN, *Grad. S.P. Sc.*	C. P. Ry., Construction Dept. Winnipeg, Man.
1904 June 14.	BOURGEOIS, BENJAMIN (*q*)	Three Rivers, P.Q.
1898 Dec. 20.	BOURGEOIS, JOHN (*q*)	Three Rivers, Que.
1899 Jan. 5.	BOWDEN, WILLIAM A. (*q*)	Address wanted.
1899 Mar. 16. S. 1903 Apr. 23. A.M.	BOWMAN, ARCHIBALD A.	Can. Rand Drill Co., Montreal.
1892 Apr. 8.	*Bowman, Leander Meyer*	
1899 Jan. 4.	BOYER, AURELIEN (*q*)	205 Daly Ave., Ottawa.
1903 Oct. 8.	BRANDEIS, CHARLES	160 St. James St., Montreal.
1901 Apl. 25. S. 1903 May 21. A.M	BRAY, LENNOX T., *Grad. S.P. Sc.*	Amherstburg, Ont.
1899 Jan. 4.	BROOKE, JOHN (*q*)	Box 77, St. Roch de Quebec,
1902 Apr. 10.	BRUNEL, WILLIAM H.	Dept. Marine, Ottawa.
1897 May 6. S. 1898 Dec. 8. A.M.	BURNETT, JAMES AUBRY	Mont. Lt. Ht. & Pr. Co., Montreal.
1900 Oct. 11. S. 1904 Nov. 17 A.M.	BUCKE, HAROLD L.	Trans-Cont. Ry., Winnipeg, Man.
1887 Feb. 24.	CAIRNIE, GORDON F.	Address wanted.
1904 Jan. 14.	CAMP, WILLIAM J.	Can. Pac. Telegraphs, Montreal.
1899 Dec. 21.	CAMPBELL, ALEX.	Patent Office, Ottawa, Ont.
1899 Mar. 6. S. 1902 Oct. 9. A.M.	†CAPE, EDMUND G. M., B.Sc.	23 Bd. Trade Bdg., Montreal.
1904 Nov. 17.	CARPENTER, HENRY S., B.A. Sc.	Gamebridge, Ont.

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1895 May 23.	CASGRAIN (HON.), JOS. P. B.	180 St. James St., Montreal.
1904 Jan. 14.	CAUSLEY, JOHN.....	901 Seymour St., Vancouver, B.C.
1899 Oct. 12.	CHALMERS, JOHN	62 Annette St., Toronto Junction, Ont.
1887 Feb. 24.	CHALONER, CHARLES	Dept. Pub. Works, Ottawa.
1896 Dec. 17.	CHAPLEAU, SAMUEL JEFFERSON.	P.O. Box 345 Ottawa, Ont.
1899 Jan. 5.	CHARBONNEAU, T. J. (*q*)	15 St. Lambert Hill, Montreal.
1887 Jan. 20. S. 1894 Dec. 20. A.M.	†CHILDS, ARTHUR EDWARD, B.A.Sc.	131 State St., Boston, Mass.
1899 Jan. 15.	CHOPIN, ULYSSE (*q*).....	20 St. James St., Montreal.
1903 Apr. 23.	CLARK, FRANKLIN	H.M. Dockyard, Halifax, N.S.
1900 Feb. 13.	*Cleveland, Frederick Albert* (*q*).	
1904 Dec. 15.	CLIFFORD, WILLIAM ..... C.E. *(Tor. Univ.)*	H. N. O. Ry., Heaslip, Ont
1903 Apr. 23.	CODE, ABRAM SILAS	Alvinston, Ont.
1897 May 6. S. 1899 Jan. 5. A.M.	†COLPITTS, WALTER W.	Asst. Chief Engr., K.C.M. & O. Ry., Kansas, Mo., U.S.A.
1899 Mar. 16.	CONNOR, ARTHUR WILLIAM C.E. *(Tor. Univ.)*	66 Sussex Ave., Toronto.
1889 Mar. 14 S. 1897 May 6. A.M.	COPELAND, LOUIS BENJAMIN....	St. Lambert, P.Q.
1898 Mar. 24. S. 1904 Apl. 14. A.M.	CORRIVEAU, R. DE B.	Dept. Pub. Wks., Ottawa.
1889 Dec. 19. S. 1899 May 25. A.M.	†COSTIGAN, JAS. S., B.A.Sc....	494 Grosvenor Ave., Westmount.
1904 Apl. 14.	COTTON, MILES P.	C. P. Ry., Winnipeg, Man.
1892 Jan. 28. S. 1899 Dec. 21. A.M.	†CREICHTON, FRANK ALBRO .	Dartmouth, N.S.
1892 Mar. 11.	CROSSLEY, FREDERICK.....	C. P. Ry., Winnipeg Man.
1895 May 23.	CRUMPTON, ARTHUR.....	G.T.R., Montreal.

1904 Jan. 14.	DARLING, E. HOWARD, *Grad. S.P. Sc.*	281 Hannah St. W., Hamilton, Ont.
1899 Nov. 14. S. 1895 Dec. 19. A.M.	DAWSON, ALEX. SCOTT, B.A.Sc...	Division Engineer C.P.R., Calgary, N.W.T.
1887 June 28. S. 1892 Apr. 8. A.M.	DAWSON, GEO. HERBERT, B.A. Sc.	541 Hastings St., Vancouver, B.C.
1902 Apr. 10.	*Day, Geo. A*..	
1900 Dec. 13.	DECARY, ALBERT R. (*q*).....	23 St. Louis St., Quebec.
1899 May 25.	DESROSIERS, LOUIS A.	Public Works Dept. Ottawa, Ont.

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1899 Jan. 31.	DESY, L. A. (*q*)	Sorel, P.Q.
1903 Apr. 23.	DEVEREUX, FRANCIS ALGERNON	76 Bay St., Victoria, B.C.
1902 Oct. 9.	DILL, CHARLES W., GRAD. S.P. Sc.	Genl. Mgr. Cons. & Paving Co., McKinnon Bdg., Toronto.
1898 Mar. 8.	DORE, J. EMERY	City Hall, Montreal.
1890 May 22. S. 1901 Apr. 25. A.M.	DOUGLAS, JAMES A.	5 Springfield Ave., Westmount.
1887 June 25.	DREWRY, WILLIAM STEWART ..	New Denver, B.C.
1902 Dec. 18 S. 1904 Dec. 18. A.M.	DRUMMOND, FRANK S.	C. P. Ry., North Bay, Ont.
1889 Mar. 14.	†DRUMMOND, THOS, B.A.Sc.	34 St. Matthew St., Montreal.
1899 Mar. 16. S. 1904 Jan. 14 A.M.	DUCHASTEL DE MONTROUGE, JULES, B.A.Sc....	227 Elm Ave., Westmount.
1898 Mar. 11. A. 1901 Nov. 21. A.M.	DUCK, HENRY F.	Norfolk House, 7 Laurence Pountney Hill, London, E.C., Eng.
1902 May 22.	DUCKWORTH, WALTER R.....	Dom. Bridge Co., Montreal.
1890 Apr. 10. S. 1896 June 18. A.M.	*Duff, John Andrew*.....	
1891 May 21. S. 1900 Oct. 11. A.M.	DUFF, WILLIAM ARCHIBALD ...	49 Crescent St., Montreal.
1894 Mar. 29. S. 1902 Dec. 18. A.M.	DUFRESNE, ALEXANDER R.....	Public Works Dept., Lockport, Man.
1898 Mar. 8.	DUFRESNE, L. ACHILLE.....	Sherbrooke, Que.
1899 Mar. 16. S. 1902 Dec. 18. A.M.	DUNCAN, GAYLEN R..... .	Three Rivers, P.Q.
1898 May 10.	DU TREMBLAY, P. P. V.	Ste. Anne de la Perade, P.Q.
1894 May 29. S. 1903 May 21. A.M.	†DYER, W. E. L.	Bellevue Flats, Montreal.
1888 Dec. 6. S. 1899 Mar. 16. A.M.	ELLACOTT, CHARLES H. B.A. Sc.....	Dept. Public Works, Regina, N.W.T.
1898 Dec. 8.	ELMSLEY, R. SHERWOOD.....	13 Elmsley Pl., Toronto.
1903 Oct. 8.	EVANS, J. W.	Deseronto, Ont.
1902 Dec. 18.	EVANS, REGINALD B.....	Orillia, Ont.
1892 Nov. 11.	EWING, JAMES.....	Engineer's Department, C.P.R. Montreal.
1899 Oct. 12.	FAIRBAIRN, JOHN M. R. F., *Grad. S.P. Sc.*	Chief Engineer's Off., C. P. Ry., Montreal.
1887 Nov. 4. S. 1900 Oct. 11. A.M.	FELLOWES, FREDERICK LYON...	1 Winchester Ave., Montreal.
1893 Oct. 12.	FITZ-GIBBON, ROBT.	P.O. Box 426, Montreal.
1901 Oct. 8.	*Fitzpatrick, J. D. A.* (*q*)	
1887 Jan. 20.	FLEMING, SANDFORD H.	Victoria Chambers, Ottawa.

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1887 Jan. 25. S. 1897 Dec. 9. A.M.	FORNERETT, V. F. W.	Dept. Public Works, Ottawa.
1899 May 25.	FORD, WILLIAM B.	Wabana Mine, Wabana, Nfld.
1900 Apr. 12.	FORWARD, EDWIN ALBERT, *Grad. S.P. Sc.*	Iroquois, Ont.
1898 Mar. 24.	*Fraser, Joseph W.*	
1892 Mar. 11.	FRIPP, FRED. BOWLES	Canadian Ship Canal, Sault Ste. Marie, Ont.
1899 Mar. 16.	FUSEY, L. ERNEST F.	409 Drolet St., Montreal.
1899 Oct. 12.	GALBRAITH, ROBERT AYR	Carleton Place, Ont.
1899 Jan. 5.	GALLAGHER, JEREMIAH (*q*)	City Hall, Quebec.
1899 Feb. 14.	GARDNER, ROBERT (*q*)	Messrs. R. Gardner & Sons, Nazareth St., Montreal.
1887 Feb. 3.	GARDINER, EDWARD	St. Catharines, Ont.
1899 Jan. 5.	GASTONGUAY, J. N. (*q*)	Quebec.
1898 Dec. 22.	*Gauthier, H. A.*	
1887 Jan. 20.	GAUVIN, CHAS. EDWARD	Quebec.
1896 Dec. 17.	GENEST, ARTHUR T.	Dept. Rys. and Canals, Ottawa, Ont.
1901 Nov. 21.	GILL, L. W.	School of Mining, Kingston, Ont.
1905 Mar. 14.	GIRARD, JOSEPH EMILE (*q*)	Dept. Lands, Mines, etc., Quebec.
1887 June 25.	*Giroux Nap. Julien*	
1892 May 20.	†GOING, ALVAH SEYMOUR	36 Board of Trade Building. Victoria, B.C.
1889 May 23. S. 1901 Apr. 25. A.M.	GOODWIN, E. P.	Address wanted.
1894 May 29. S. 1902 Apl. 10 A.M.	GOODWIN, JAMES B., B.A.Sc.	Box 356, Niagara Falls, Ont
1902 Dec. 18. S, 1904 Dec. 15. A.M.	GOUGH, RICHARD T., B.Sc.	C. P. Ry., Montreal.
1899 Mar 16.	GOULET, JOSEPH A. G.	Can. Genl. Elec. Co., Peterborough.
1898 Mar. 16.	GRANT, GORDON	Construction Dept. C.P.R., Montreal.
1892 Dec. 18.	GRANT, WILLIAM F., *Grad. S.P. Sc.*	540 Dovercourt Road, Toronto
1892 Apr. 8. S. 1899 May 25. A.M.	GREENBERG, LOUIS, B.A.Sc.	54 West 88th St., New York.
1897 Dec. 9.	GREENE, N. HANSON	207 St. James St., Montreal.
1901 May 31. S. 1904 Jan. 14. A.M.	GRUNDY, GEO. G.	Témiscouata Ry., Rivière-du-Loup, P.Q.
1887 Dec. 7.	GUAY, JEAN F.	Plessisville, P.Q.
1897 Dec. 9. S. 1904 Apl. 14. A.M.	GZOWSKI, CASIMER S., JR.	277 Bathurst St., Toronto.
1889 Dec. 19.	HANNAFORD, R. MAITLAND	Lachine, P.Q.

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1897 Dec. 9.		HANNING, GEORGE FOSTER, *Grad. S.P. Sc.*	Box 349, Edmonton, Alta.
1899 Oct. 12.	S.	HARE, W. ALMON, B.A. Sc.	37 Grenville St., Toronto.
1903 May 21.	A.M.		
1886 Mar 12.		HARRIS, JOHN WALTER	City Hall, Winnipeg, Man.
1895 Feb. 28.		HAYCROFT, JAS. ISAAC	Fontenay, Ocean St., Woollahra, N.S.W., Australia.
1896 Dec. 17.		HAZEN, HUGH T.	Parry Sound, Ont.
1892 May 11.		HEBERT, EDMUND ANT	Apartado No. 199, Oaxaco, Mexico.
1887 Feb. 24.		HECKMAN, JOS. WM., B.E.	877 Dorchester St., Montreal.
1898 Dec. 22.		HEDDLE, JOHN REID	City Engineer's Office, Hamilton, Ont.
1903. Oct. 8.		HENDERSON, RICHARD A.	Edmonton, Alta.
1892 May 20.		HENDERSON, THOS. ROBERT	Maspherson & Henderson, Savings Bank Bdgs., Capetown, S. A.
1899 Jan. 4.		HENRY, GABRIEL (*q*)	30 St. Famille St., Quebec.
1892 May 20.		HENDRY, WILLIAM A.	Windsor, N.S.
1899 Jan. 9.		†HERDT, LOUIS A. (*q*)	McGill University, Montreal.
1893 Oct. 12.		HESKETH, JAS. A.	Engineer's Office, C.P.R., Winnipeg, Man.
1899 Oct. 12.		HETHERINGTON, FRED. JAS.	Quebec.
1893 Oct. 12.		HIGMAN, ORMOND	Chief Electrician Inland Revenue Dept., Ottawa.
1895 Dec. 19.	S.	HOLMES, ARCH. R.	Link Belt Engine Co., Philadelphia, Pa.
1901 Apr. 25.	A.M.		
1898 Dec. 8.	S.	HOULISTON, JOHN (*q*)	Three Rivers, Que.
1900 Jan. 9.	A.M.		
1899 Dec. 21.		HUGHES, HENRY THORSBY	Stanley Barracks, Toronto.
1887 Apl. 14.	A.	HUNTER, ROBERT EASTON	644 St. Denis St., Montreal.
1900 Apl. 12.	A.M.		
1893 Oct. 12.		*Husbands, Arthur L.*	
1891 Oct. 8.	S.	HUTCHEON, JAMES, *Grad. S.P. Sc.*	Guelph, Ont.
1900 Oct. 11.	A.M.		
1902 Dec. 18.	S.	HOUSTON, LEVIN J., JR.	Chesapeake & Ohio Ry., Ashland, Ky., U.S.
1903 May 21.	A.M		
1887 Feb. 24.	S.	IRVINE, JOHN	Harriston, Ont.
1898 May 19.	A.M.		
1898 Mar. 24.	S.	†IRVING, T. T.	Engineer's Office, Bonaventure Station, Montreal.
1902 Dec. 18.	A.M.		
1899 Jan. 5.		†JANIN, GEORGE (*q*)	City Hall, Montreal.
1898 Mar. 24.	S.	JAQUAYS, HOMER M.	11 Lorne Ave., Montreal.
1898 Dec. 22.	A.M.		
1904 Apl. 14.		JENSSEN, LAURITZ N.	C/o C. P. Ry., Bolton, Ont.
1895 Dec. 19.	S.	JERMYN, FREDERICK L.	Address wanted.
1901 Jan. 17.	A.M.		

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1901 Apr. 25.		JOANNIDIS, A. G.	Engineering Dept., Egyptian State Ry., Cairo, Egypt.
1901 Nov. 21.		JORDON, H. L.	Asst. Engr. C. P. Ry., Montreal.
1902 May 22.		JORGENSON, G. EMILE	V. W. & Y. Ry. Co., Vancouver, B.C.
1904 Jan. 14.	S.	KAELIN, FREDERICK T.	1724 Notre Dame St., Montreal.
1904 Apl. 14.	A.M.		
1887 June 25.		g†KEELEY, DAVID HERBERT.	Govt. Tel. Service, Ottawa.
1902 Apr. 10.		KELLER, LOUIS	158 Ann St., Hull, P.Q.
1893 Apr. 20.		KER, NEWTON JAMES	City Engineer, Ottawa.
1901 Apr. 25.		KERR, A. T.	Orillia, Ont.
1890 Nov. 20.	S.	KIPPEN, HORACE BRUCE	56 Cecil St., Toronto.
1894 Dec. 20.	A.M.		
1899 Jan. 5.		KIRK, THOMAS (*q*)	76 St. Gabriel St., Montreal.
1904 Dec. 15.		KRUMM, J. C. N. B.	C/o Trans.-Cont. Ry., Pohenagamcoke, P.Q.
1899 Mar. 16.		LABERGE, FRANCOIS CHARLES	71 St. James St., Montreal.
1889 Feb. 14.	S.	*Lafontaine, Emery*	
1899 Jan. 4.	A.M.		
1899 Jan. 5.		LAFOREST, J. O. ALFRED (*q*)	Box 33, Levis, P.Q.
1904 Apl. 14.		LAMB, THOMAS EDWARD	211 Bd. of Trade, Montreal.
1899 Mar. 16.		LAMB, HENRY JOHN	Burlington, Ont.
1902 Oct. 9.		LANG, GEORGE M.	Address wanted.
1888 June 27.		*Langevin, H. Laforce*	
1894 Mar. 29.	S.	LARMONTH, JOHN HERBERT	Peterborough, Ont.
1904 Apl. 14.	A.M.		
1899 Jan. 5.		LAROCHELLE, A. H. (*q*)	Box 24, Levis, Que.
1903 May 21.		LAROCHELLE, JOSEPH E.	Box 24, Levis, P.Q.
1898 Dec. 20.		LAURIN, JAMES (*q*)	78 Laval Ave., Montreal. Montreal.
1899 Oct. 12.		LAW, GERALD LESLIE	Construction Dept. C.P.R., Regina, N.W.T.
1904 Dec. 15.		LEACH, FRANCIS E.	Revelstoke, B.C.
1893 May 18.		LECKIE, ROBERT G. E.	Republic, State of Washington, U.S.A.
1898 Dec. 8.		LEECH, CHARLES SAMUEL	C.P.R., Montreal.
1898 Dec. 20.		*Leduc, C. (q)*	
1898 Dec. 20.		LEFEBVRE, F. X. (*q*)	No Address.
1898 May 19.	S.	LEFEVRE, ALFRED G. TULLY	C/o of Pekin Syndicate, Shanghai, China.
1899 Dec. 21.	A.M.		

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1898 Feb. 17.	LEGRAND, JOSEPH G.	138 Champ de Mars, Montreal.
1901 May 7. S. 1902 Apr. 10. A.M.	LEMAN, BEAUDRY	Shawinigan Falls, Que.
1899 Jan. 4.	LEMIRE, J. T. (*q*)	No Address.
1899 Jan. 5.	LEMOINE, C. E. (*q*)	135 St. Peter St., Quebec.
1889 Dec. 19.	LEPROHON, C. DE BELLEFEUILLE	32 Chomedy St., Montreal.
1894 Mar. 29.	LESLIE, W. L.	Dept. Rys. & Canals, Ottawa.
1898 Dec. 20.	LESAGE, SIMON (*q*)	17 Place d'Armes Hill, Montreal.
1894 Dec. 20.	LEWIS, DAVID OWEN	21 Bernard Ave., Toronto.
1896 Mar. 12. S. 1899 Mar. 16. A.M.	LINDSAY, HAMILTON	Address wanted.
1901 May 14.	LIPPE, A. W. (*q*)	St. Herminigilde, Que.
1898 Dec. 8.	LOCKE, THOMAS JOHNSON	Care, C. E. W. Dodwell, Esq., Halifax, N.S.
1899 Jan. 4.	LOCKHART, H. R. (*q*)	111 Lewis, Ave., Montreal.
1903 Apr. 23.	LOGAN, WILLIAM A.	Prescott, Ont.
1887 Feb. 24. S. 1900 May 31. A.M.	LOIGNON, ERNEST	360 Seigneurs St., Montreal.
1904 Dec. 15.	LONGLEY, HORACE	Bridgewater, N.S.
1890 Apr. 10. S. 1897 Mar. 11. A.M.	†LORDLY, HENRY R., C.E. (*Cornell*) (*Librarian.*)	36C. Drummond St., Montreal.
1887 Dec. 1. S. 1893 Apr. 19. A.M.	†LOVELACE, EDGAR S. M. B.A.Sc.	457 Elm Avenue, Westmount, Que.
1895 Dec. 19.	MCCALLUM, ALEX. CAMPBELL	P.O. Box 368, Peterboro, Ont.
1897 May 6. S. 1899 Mar. 16. A.M.	MCCARTHY, GEORGE A.	Box 465, North Bay, Ont.
1898 Feb. 17.	MCCRADY, F. W.	1115 Hare St., Vancouver, B.C.
1899 May 25.	MCCUBBIN, GEORGE A.	City Engineer's Office, St. Thomas, Ont.
1891 Apr. 9.	MCCULLOCH, ANDREW LAKE, *Grad. S.P. Sc.*	City Engineer, Nelson, B.C.
1887 Feb. 24. S. 1892 Jan. 28. A.M.	MCDOWALL, ROBERT, GRAD. S.P. Sc.	Owen Sound, Ont.
1888 May 28.	MCGREEVY, CHARLES	Dept. Marine, Ottawa.
1904 Jan. 14.	MCINTOSH, FREDERICK J.	c/o Mackenzie Mann & Co., Winnipeg, Man.
1899 Oct. 12.	MCLAREN, JOHN	Erwood, Sask.
1899 May 25.	MCLEAN, NORMAN B.	Dept. Pub. Works, Ottawa, Ont.
1899 Mar. 16. S. 1902 Apr. 10. A.M.	MCLEOD, NORMAN M., B.Sc.	Canada Foundry Co., Toronto.

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1899 May 25.	McLEAN, WILLIAM A.	Parliament Bldgs., Toronto, Ont.
1897 May 20.	McMULLEN, W. E.	C.P.R., St. John, N.B.
1894 Mar. 29. S. 1901 Nov. 21. A.M.	McPHERSON, A. J.	Dawson, Y.T.
1904 Apl. 14.	McRAE, JOHN BELL	173 Elgin St., Ottawa.
1896 June 18. S. 1900 May 31. A.M.	MACDONALD, WM. ANGUS	Box 163, Fairmount, W. Va.
1903 Apr. 23.	MACDOUGALL, ALEXANDER	Citizens' Bdg., Ottawa.
1900 Apr. 12. S. 1900 May 31. A.M.	MACDOUGAL, ARCHIBALD JOSEPH R.	323 Besserer St., Ottawa, Ont.
1901 Apr. 25.	MACDOUGALL, G. D.	Dom. I. & S. Co., Sydney, C.B.
1889 May 25.	MACFARLANE, ALBERT G.	Almonte, Ont.
1887 Jan. 20. S. 1889 Dec. 21. A.M.	MACFARLANE, M.C.	Almonte, Ont.
1904 Nov. 17.	MACGILLIVRAY, ALEXANDER M.	Care, Mackenzie Mann & Co., Bridgewater, N.S.
1894 Mar. 29.	MACGREGOR, J. GRANT	Box 264, Goderich, Ont.
1902 May 22.	MACINTYRE, ROBERT W.	Asst. Chief Engr. Pub. Wks. Dept., Regina, N.W.T.
1888 May 28.	MACKENZIE, JAMES W.	Prov. Engineer's Office, Halifax, N.S.
1899 Dec. 21. S. 1900 Oct. 11. A.M.	MACKERRAS, JOHN D.	Sierra Madre, California.
1901 Apr. 25.	MACKIE, F. G.	Address wanted.
1903 May 21.	MACLAREN, GEORGE P.	Shelburne, N.S.
1902 Apr. 10.	MACLEAN, THOMAS A.	Charlottetown, P.E.I.
1897 May 20. S. 1901 Jan. 17. A.M.	†MACPHAIL, WM. M.	Roadways Dept., City Hall, Toronto, Ont.
1902 Apr. 10.	MACTAGGART, NEIL B.	125 Spencer Ave., Toronto.
1899 June 13.	MAILHIOT, JOSEPH EDMOND (*q*)	Address wanted.
1897 Mar. 11.	*Marion, L. Jos*	
1897 Dec. 9.	*Marion, J. A.*	
1899 Jan. 4.	MASSEY, ARTHUR W. K. (*q*)	Dom. Bridge Co., Montreal.
1895 Dec. 19. S. 1899 May 25. A.M.	MATHESON, ARTHUR J.	211 Stewart St. Ottawa, Ont.
1902 Apr. 10.	MATHESON, EDWARD S.	Trans-Cont. Ry. Survey, Chipman, N.B.
1899 Oct. 12.	†MAUNSELL *(Major)*, GEO. STOPFORD	Dept. Militia and Defence, Ottawa, Ont.
1903 Apr. 23.	MAXIMOFF, SERGIUS P.	Fabalkanski pr. 67, St. Petersburg, Russia.
1904 Dec. 15.	MERRILL, EDWARD B.	16 King St. W., Toronto.
1899 Jan. 23.	MICHAUD, JOSEPH LOUIS (*q*)	Ste. Anne de Bellevue, Que.

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1902 Dec. 18.	MILES, HAROLD R.	Chapleau, Ont.
1891 Jan. 29.	MILLICAN, CHAS. ARTHUR	Box 525 Winnipeg, Man.
1898 Dec. 2.	MILNE, CHARLES G., *Grad. S.P. Sc.*	Hamilton, Ont.
1904 Apl. 14.	MONTREUIL, JOSEPH O.	9½ St. John St., Quebec.
1898 June 14.	MONSARRAT, C. N. (*q*)	C.P.R., Montreal.
1903 Apr. 23.	MOORE, ERNEST VIVIAN, B.Sc.	Box 332, Peterborough, Ont.
1897 May 6.	MOORE, JOHN HARRISON, *Grad. S.P. Sc.*	Smith's Falls, Ont.
1901 Jan. 17.	MORITZ, CHAS. HOLLAND	Shawinigan Falls, P.Q.
1902 Dec. 18.	MOSS, CHARLES S.	Engineer's Office, C.P. Ry., Revelstoke, B.C.
1898 Dec. 22.	MOTLEY, PHILLIPS BATHURST.	Chief Engineer's Office, C.P.R. Montreal.
1894 Mar. 29. S. 1899 Mar. 16. A.M.	MUDGE, ARTHUR L., B.A. Sc.	393 Mountain St., Montreal.
1899 Jan. 9.	MULLARKEY, JOHN P. (*q*)	Guardian Bdg., Montreal.
1904 Jan. 14.	MURPHY, JOHN	174 MacLaren St., Ottawa.
1890 May 19.	MURPHY, JOHN J.	Trans-Cont. Ry., Cobourg, Ont.
1904 Nov. 17.	MURPHY, MARTIN J., JR.	Intercolonial Ry., Moncton, N.B.
1898 Feb. 8.	MURRAY, WILLIAM ALEXANDER.	164 St. James St., Montreal.
1899 Jan. 9.	NELSON, J. M. (*q*)	Harbour Office, Montreal.
1891 Oct. 8. S. 1894 Oct. 11. A.M.	NEWMAN, WM., *Grad. S.P. Sc.*	Box 442, Windsor, Ont.
1899 Jan. 5.	O'DONNELL, HUGH (*q*)	City Hall, Quebec.
1887 Feb. 3.	O'HANLY, JOHN MITCHELL	352 Daly St., Ottawa.
1887 Apr. 14. S. 1899 Mar. 16. A.M.	†OGILVY, ROBERT F.	1144 Dorchester St., Montreal.
1887 Oct. 16.	OLIVER, STUART STIRLING	Quebec.
1896 June 18.	ORROCK, JOHN WILSON	C.P.R., Montreal.
1903 Oct. 8.	OSBORNE, G. F. FOLGER.	C/o Messrs. King, King & Co., Bankers, Fort, Bombay, India.
1887 Jan. 20. S. 1891 Nov. 19. A.M.	†PALMER, ROBT. ED., B.A.Sc.	Rio Tinto Mine, Prov. Huelva, Spain.
1887 Feb. 24.	PAPINEAU, LOUIS G.	80½ St. Hubert St., Montreal.

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1899 Jan. 5.	PARADIS, PAUL (*q*)	Resident Engineer, Public Works Dept., Calgary, N.W.T.
1894 Mar. 29. S. 1899 Mar. 16. A.M.	PARENT, PAUL ETIENNE	Dept. Marine, Quebec.
1900 Nov. 22.	PARKE, RODERICK J. McD.	Janes Building, Toronto.
1902 Dec. 18.	PARKS, JOHN H.	Address wanted.
1899 May 25.	PARKER, SAMUEL H.	G.T.R., Montreal.
1901 Nov. 21.	PARKINSON, RICHARD H.	Fairview, B.C.
1887 Feb. 24.	PARISEAU, LOUIS S.	616 St. Denis St., Montreal.
1902 Oct. 9.	PARSONS, W. F. CECIL	Address wanted.
1888 Feb. 9. S. 1894 Dec. 20. A.M.	PEARSE, THOS. E. E.	Newport News, Va.
1890 Apr. 10. S. 1894 Oct. 11. A.M.	*Pedder, James R.*	
1897 Apr. 22.	PERLEY, GEO. E.	Dept. Pub. Works, Ottawa.
1898 Oct. 11.	PERRAULT, MAURICE (*q*)	15 St. Lambert Hill, Montreal.
1887 Jan. 20.	PERREAULT, EDWARD EUGENE.	81 Daly Ave., Ottawa.
1898 Dec. 20.	PERRIN, VINCENT (*q*)	Geological Survey of Canada, Ottawa.
1898 Nov. 8.	PERRON, P. A. (*q*)	Room 101, Dept. Pub. Works, Ottawa.
1904 Nov. 17.	PHILLIPS, GEORGE	H. M. Dockyard, Esquimault, B.C.
1899 Mar. 16.	PICHÉ, JOSEPH PIERRE.	Address wanted.
1904 Nov. 17.	PICKERING, FRANCIS ALEX.	68 South Park St., Halifax, N.S.
1897 Mar. 11.	PIGOT, C. J.	Q. Ry. Lt. & Pr. Co., Quebec.
1899 Jan. 5.	PINET, A. J. (*q*)	Address wanted.
1887 Feb. 24. S. 1894 Jan. 4. A.M.	PINHEY, CHAS. H., *Grad. S.P. Sc.*	110 Wellington St., Ottawa.
1902 Oct. 9.	PITCHER, FRANK H.	62 Imperial Bdg., Montreal.
1904 Apl. 14.	POOLE, EDWARD GODFREY	Jas. Bay Ry. Co., Bala., Ont.
1893 Apr. 20.	POTTER, ALEXANDER	150 Nassau St., New York.
1902 Apr. 10.	PUTNAM, HARTWELL N.	Bridgewater, N.S.
1902 Apr. 10.	RAINBOTH, JOHN	Aylmer, P. Q.
1890 May 23. S. 1901 Jan. 17. A.M.	RANKIN, JOHN, JR., B.A.Sc.	C. N. Ry., Osler, Sask.
1887 June 25. S. 1895 Feb. 28. A.M.	REID, WM. MURRAY, B.A.Sc.	555 Grosvenor Ave., Montreal.
1904 Jan. 14.	REVELL, GEORGE E., B.A.Sc.	Huronian Co., Ltd., Turbine, Algoma Dist., Ont.

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1887 Feb. 24. S. 1895 May 23. A.M.	RICHARDSON, GEO. H., *Grad. S.P. Sc.*	Asst. City Engineer, Ottawa, Ont.
1892 Mar. 11. S. 1899 May 25. A.M.	ROBERT ALPHONSE, M.A., B.A.Sc.	109 Water St., Ottawa, Ont.
1899 Mar. 16. S. 1902 May 22. A.M.	ROBERTSON, PHILIP, W. K.	Pinos Altos Mines Co., Chihuahua, Mexico.
1903 May 12.	ROBERTSON, H. H. (*q*)	Georgian Bay Ship Canal Survey, Campbell's Bay, P.Q.
1895 May 23. S. 1899 Jan. 31. A.M.	ROGERS, ROBT. P. (*q*)	Box 533 St. Catharines, Ont.
1904 Jan. 14.	ROSS, DONALD A.	Can. Nor. Ry., Winnipeg, Man.
1902 Apr. 10.	ROSS, DONALD W., JR.	Phoenix Bridge Co., Montreal.
1894 Dec. 20.	ROSS, GEORGE, B.A.Sc.	Welland, Ont.
1899 May 25.	ROY, ADOLPHE V.	425 St. James St., Montreal.
1898 Mar. 8.	ROY, GEORGE P.	28 Rue Lachevrotière, Quebec.
1904 Apl. 14.	ROSS, HENDRY J. D.	Hintonburgh, Ottawa, Ont.
1903 May 21.	ROY, JOSEPH A.	Dom. Bridge Co., Montreal.
1887 Feb. 24.	ROY, JOSEPH R.	Pub. Wks. Dept., Ottawa, Ont.
1898 Dec. 22.	ROY, R. MAITLAND	270 Main St., Hamilton, Ont.
1902 Apr. 10.	RUSSELL, HAROLD A.	Dartmouth, N.S.
1893 May 18. S. 1899 May 25. A.M.	RUSSEL, ROBERT K., *Grad. S.P. Sc.*	North Bay, Ont.
1899 Jan. 4.	RUSSELL, WILLIAM R. (*q*)	Address wanted.
1899 Feb. 14.	RUTHERFORD, STEWART F. (*q*)	61 Rosemount Avenue, Westmount, Que.

1904 Jan. 14.	SAMMETT, MATTHEW A.	Lt., Ht. & Pr. Co., Montreal.
1895 May 23. S. 1900 Nov. 22. A.M.	SCAMMELL, JOHN KIMBALL, B.A. Sc.	Dept. Pub. Works, St. John, N.B.
1904 Nov. 17.	SCHRIEBER, OWEN P.	Trans-Cont. Ry., Ottawa.
1904 Jan. 14.	SCHWABE, VINCENT H.	Victoria, B.C.
1888 Mar. 22. S. 1896 Mar. 12. A.M.	SCHWITZER, JOHN EDWARD, B.A.Sc.	C.P.Ry., Winnipeg, Man.
1896 Jan. 9. S. 1902 Apr. 10 A.M.	SCOTT, WALTER M.	Box 321, New Glasgow, N.S.
1902 Apr. 10. S. 1902 Dec. 18. A.M.	SHAW, HERBERT H.	Charlottetown, P.E.I.
1900 Oct. 11. S. 1902 Dec. 18. A.M.	SHERWOOD, LUMAN	City Engineers Off., Toronto, Ont.
1900 Nov. 13.	SHEPPARD, C. G. (*q*)	Aylmer, Que.
1887 Feb. 24. S. 1900 Nov. 22. A.M.	SHILLINGLAW, WALTER HENDERSON	Box 182, Brandon, Man.
1899 Jan. 23.	SIROIS, J. EUSTACHE (*q*)	Ste. Anne de la Pocatière, Que.

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1899 Dec. 21.		SIMMONS, THOS. LOCKWOOD	Dept. Rys. & Canals, Ottawa.
1896 Dec. 17.		SIMONDS, FRANCIS EDWARD ...	Leduc, N.W.T.
1904 Nov. 17.		SIMPSON, THOMAS T.	55 Sparks St., Ottawa.
1898 Mar. 24.		SKAIFE, LEWIS	20 St. James St., Montreal.
1887 May 12.	S.	SKAIFE, WILFRED T., B.A.Sc...	630 Sherbrooke St., Montreal.
1888 Feb. 9.	A.M.		
1899 Feb. 14.		SMAILL, ALBERT E. (*q*).....	360 Victoria Avenue, Westmount, Que.
1894 Dec. 20.	S.	†SMITH, ANGUS, *Grad. S.P. Sc.*	Stratford, Ont.
1899 Dec. 21.	A.M.		
1898 Dec. 20.		SMITH, ARTHUR (*q*).....	Quebec Observatory, Quebec.
1904 Jan. 14.	S.	SMITH, JULIAN C.	Bk. Ottawa Bdg., Montreal.
1904 Apl. 14	A.M.		
1902 Dec. 18.		SMITH, HERBERT NEVILE	Chilliwack, B.C.
1895 May 23.	S.	SMITH, OWEN W.	Regina, N.W.T.
1901 Apr. 25.	A.M.		
1904 Jan. 14.		SMITH, PERCY H.....	232 Brittain St., St. John, N.B.
1887 June 25.		*Smith, Wm. Hy. Chatterton*.....	
1899 Jan. 31.		*Spenard, J. (q)*	
1888 June 27.	S.	SPENCE, ALEXANDER W.	Trent Canal Office, Peterboro, Ont.
1896 Mar. 12.	A.M.		
1900 May 31.		STEAD, GEOFFREY	Box 4, Chatham, N.B.
1898 May 19.		ST. LAURENT, ARTHUR	Dept. of Pub. Works, Ottawa.
1891 Nov. 19.		STEELE, EDWARD CHAS.	Box 309, S. S. Marie, Ont.
1897 Dec. 9.		STEWART, ANGUS M.	Samana and Santiago Ry., Sanchez, San Domingo.
1901 Nov. 21.		STIMPSON, A. W. H.	32 Central Chambers, Ottawa.
1888 Mar. 22.	S.	†STONE, ERNEST ALBERT, MA.E.	Can. Foundry Co., Toronto.
1895 Feb. 28.	A.M.		
1898 Feb. 17.		†STUART, ALLEN K.	Whitewater Deep Mine, Whitewater, B.C.
1888 Mar. 22.	S.	STUART, HENRY B., B.A.Sc....	G.T.R., Montreal.
1898 Feb. 17.	A.M.		
1899 Mar. 16.		SULLIVAN, JOHN HUGH	Box 49, Valleyfield, Que.
1899 Oct. 12.		SULLIVAN, WILLIAM HENRY ...	Charlottetown, P.E.I.
1902 Apl. 10.	S.	SCOTT, THOMAS S.....	Niagara Falls Centre, Ont.
1903 Oct. 8.	A.M.		
1898 Oct. 11.		TALBOT, P. CLEOPHAS (*q*).....	Montmagny, Que.
1898 Apr. 12.	S.	TAYLOR, FRANK	Res. Engr. C.P.R. Viger Sq. Station, Montreal.
1903 Apr. 23.	A.M.		
1901 Nov. 21.		TAYLOR, W. V., *Grad. S.P. Sc.*	Loco. & Machine Co., Montreal.
1904 Nov. 17.		THOMAS, DAVID ROSS	Rossland Club, Rossland, B.C.
1887 Jan. 20.		THOMPSON, ROSS	Dom. Coal Co., Glace Bay, C.B.
1894 Jan. 4.		†THOMPSON, WM. T., M.A.Sc....	Qu'Appelle Sta., Assa. N.W.T.

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1899 Dec. 21.		THOMSON, CLARENCE	774 Craig St., Montreal.
1904 Jan. 14.		THOMPSON, WILLIAM..	Waterson Gold Co. Ltd., Ocampo, Chihu., Mexico.
1903 Oct. 8.		THORNLEY, JULIAN	Niagara Falls, Ont.
1894 Jan. 4.	S.	THORNTON, KENNETH B.	Mont. Lt., Heat & Pr. Co., Montreal.
1899 Mar. 16.	A.M.		
1899 Jan. 4.		THURSO VON QUERFURTH, J.W. *(q)*	14 Torrance St., Montreal.
1890 Nov. 20.	S.	†TIGHE, JAMES L., B.A.Sc.	City Hall, Holyoke, Mass.
1900 May 31.	A.M.		
1889 Nov. 14.		TOMS, LEWIS WM.	Port Hammond, B.C.
1899 May 9.		TOURIGNY, HONORE B. *(q)*	Ste. Julie de Somerset, Que.
1889 Jan. 3.	S.	TREMBLAY, THOMAS	Sherbrooke, Que.
1898 Mar. 8.	A.M.		
1902 Apr. 10.		TREMBLAY, JOSEPH A.	Montmagny, P.Q.
1903 May 21.		URE, FREDERICK J.	Woodstock, Ont.
1887 Jan. 20.		VANIER, J. EMILE	5 Beaver Hall Sq. Montreal.
1898 Nov. 8.		VINCENT, ARTHUR	St. Hyacinthe, P.Q.
1902 Apr. 10.		VOGEL, CHARLES H.	Carleton Chambers, Ottawa, Ont.
1904 Jan. 14.	S.	WALLS, JOHN ABBET	Bk. Ottawa Bdg., Montreal.
1904 Apl. 14.	A.M.		
1890 Nov. 20.	S.	WAINWRIGHT, JAMES G. R., B.A.Sc.	Co|o Bareuth Record Co., Minneapolis.
1899 Oct. 12.	A.M.		
1904 Dec. 15.		WALKER, NORMAN DE C.	C. P. Ry., Montreal.
1899 Jan. 5.		WALLBERG, E. A. *(q)*	Loco. & Machine Co., Montreal.
1894 Mar. 29.		WARNER, WM. GEORGE	Box 37, Winnipeg, Man.
1898 May 10.	S	WATEROUS, CHARLES A., B.A. Sc.	Brantford, Ont.
1903 May 21	A.M.		
1901 Apr. 25.		WEATHERBE, D.	Mines Dept., Halifax, N.S.
1904 Apl. 14.		WEATHERBE, KARL, B.A., B.Sc.	Windsor, N.S.
1894 Dec. 20.		WHEATON, LEWIS H.	Mackenzie, Mann & Co., Shelburne, N.S.
1890 Apr. 10.	S.	WIGGINS, THOMAS HENRY, *Grad. S.P. Sc.*	Asst. Chief Surveyor, N.W.T. Pub. Wks. Dept., Regina, N.W.T.
1900 Nov. 22.	A.M.		
1904 Jan. 14.		WILKIE, EDWARD T.	Carleton Place, Ont.
1896 June 18.	S.	WILKIN, FREDERICK A.	Cons. Dept., C.P.Ry., Winnipeg, Man.
1903 Oct. 8.	A.M.		
1904 Nov. 17.		WILSON, ROBERT M.	Montreal Lt. Ht. & Pr. Co., Montreal.
1887 Feb. 24.	S.	WILLIAMS, M. L., B.A.Sc.	Edgewood, Georgeville, Que.
1898 Dec. 8.	A.M.		
1904 Nov. 17.		WOOD, CHARLES O.	Bank St. Chambers, Ottawa.
1887 June 22.		WOODS, JOS EDWARD	Aylmer, P.Q.

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ASSOCIATES.

(A. Can. Soc. C. E.)

Date of Membership.	*Name.*	*Address.*
1895 Dec. 19.	ALLAN, FRED. G. B.....	Deseronto, Ont.
1898 Mar. 11.	ARMSTRONG, D. N.....	Marlbank, Ont.
1902 Oct. 9.	AUSTIN, A. F. BURY.....	224 St. James St., Montreal.
1901 Apr. 25.	BOUCHER, U. P.....	386 Sherbrooke St., Montreal.
1895 Feb. 28.	BUDDEN, HANBURY A.....	125 Mackay St., Montreal.
1902 Oct. 9.	CARTER, WALTER C.....	Dom. I. & S. Co., Sydney, C.B.
1904 Apl. 14.	CAUCHON, NOULAN J. E.	136 Metcalfe St., Montreal.
1901 Jan. 17.	CHAUSSÉ, ALCIDE	279 St. André St., Montreal.
1903 Oct. 8.	CLARK, JOHN MURRAY.....	16 King St. W., Toronto.
1889 Jan. 8.	COWANS, JOHN R.....	Springhill, N.S.
1904 Jan. 14.	*Eicks, Carl F.*	
1899 Mar. 16.	EVANS, OWEN N.....	483 Temple Bldg., Montreal.
1899 Mar. 16.	FETHERSTONHAUGH, EDWARD J.....	Canada Life Bldg., Montreal.
1891 Nov. 19.	GIBSON, WILLIAM, M.P.....	Beamsville, Ont.
1904 Jan. 14.	GILMAN, FREDERICK J.....	516 Cadieux St., Montreal.
1889 Dec. 19.	HENDRIE, WILLIAM.....	Hamilton, Ont.
1888 Mar. 22.	*Isbester, James*.....	
1888 Mar. 22.	IVES, HUBERT R.....	117 Queen St., Montreal.
1893 Apr. 20.	KAMMERER, JACOB A.....	87 Jameson Ave., Toronto.
1902 Dec. 18.	LARKIN, HERBERT E.	Thorold, Ont.

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1891 Nov. 19.	McFarland, Jos. Walter....	P.O. Box 206, Vancouver, B.C.
1888 Apr. 19.	McKenzie, John.....	New Westminster, B.C.
1893 Apr. 20.	McLaren, Harry, B.A.....	67 Mansfield St., Montreal.
1889 Jan. 3.	*Molson John Henry R*.....	
1904 Nov. 17.	Morrison Thomas A.	204 St. James St., Montreal.
1903 Apr. 23.	Mussen, William H. C.	763 Craig St., Montreal.
1888 May 17.	*Osler, Britten Bath*.....	
1888 Oct. 11.	Polson, Franklin Bates.....	Polson Iron Works, Toronto.
1904 Apl. 14.	Pringle, R. E. T.	Montreal.
1901 Nov. 21.	Quirk Eugene McG.....	698 Boulevard, Ville St. Louis, Montreal.
1890 Nov. 20.	*Rathbun, Edward Wilkes*.....	
1887 Jan. 20.	*Reaves, George R*.....	
1887 June 9.	Reid, Robert Gillespie.....	Room 28, Canada Life Bldg., Montreal.
1891 Jan. 29.	*Reid, William Gillespie*.....	
1887 Jan. 20.	*Reynolds, F. H*.....	
1890 Feb. 27.	Robertson, J. C.....	Carr Bldg., Springfield, Mass.
1888 May 17.	*Ryan, Hugh*.....	
1890 Apr. 10.	*Scott, J. Philip*.....	
1890 Feb. 27.	Shearer, James Traill.....	Montreal.
1904 Jan. 14.	Stansfield, Alfred.....	McGill University, Montreal.
1888 Mar. 22.	Sutherland Kenneth.....	Kentville, N.S.
1889 Feb. 14.	Swinyard, Thomas M.....	The Hall, Gilbertsville, N.Y.
1887 May 12.	Trotter, Wallace Cuthbert.....	St. Johns, P.Q.
1888 May 17.	Van Horne, *Sir* William C., K.C.M.G.....	917 Sherbrooke St., Montreal.
1892 Jan. 28.	Weddell, Robert.....	Trenton, Ont
1904 Apl. 14.	Wilson, Harry	1570 Ontario St., Montreal.

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STUDENTS.

(Stud. Can. Soc. C. E.)

Date of Membership.	*Name.*	*Address.*
1899 Mar. 16.	ALLEN, SAMUEL JAMES.....	The Johns Hopkins College Baltimore, Md.
1903 Oct. 8.	AMIREAULT, CAMILLE..	214 Sherbrooke St., Montreal.
1900 Oct. 11.	ANDERSON, THOS. VICTOR.....	R. M. College, Kingston, Ont.
1899 Mar. 16.	ARCHER, AUGUSTUS R.....	Care, Messrs. Dormeuil Freres, 5 W. 19th St., New York.
1899 Mar. 16.	ARKLEY, LORNE MCKENZIE.....	3807 Poplar St., Philadelphia, Pa.
1904 Jan. 14.	ATKINSON, MARSHALL B.....	McGill University, Montreal.
1899 Mar. 16.	AUSTIN, CLAUDE V. C.....	Cummings Bridge, Ont.
1900 Oct. 11.	BAKER, EDWARD CARLTON.....	199 O'Connor St., Ottawa.
1895 May 23.	BAKER, HUGH C.....	Box 297, Vancouver, B.C.
1899 Mar. 16.	BAULNE, STANISLAS ALBERT.....	97 St. Denis St., Montreal.
1904 Jan. 14.	*Bay, Benedict O*.....	
1903 May 21.	BEAUBIEN, J. DE G.....	Outremont.
1898 Dec. 8.	BEAUDRY, D. L. G. DE SALABERRY.....	No Address.
1899 Mar. 16.	BECK, ALFRED E.....	149 Durocher St., Montreal.
1904 Nov. 17.	BEIQUE, PAUL A.	954 Sherbrooke St., Montreal.
1901 Apr. 25.	BELL, G. E.....	Address wanted.
1899 Mar. 16.	BELANGER, A. A.	Res. Engineer's Office, C. P. Ry.. Dalhousie Sq., Montreal.
1904 Nov. 17.	BIDWELL, LEONARD M.	C.P. Ry., North Bay, Ont.
1902 Apr. 10.	BIGGAR, HOWELL.....	68 Daly Avenue, Ottawa.
1904 Jan. 14.	BIRD, WILLIAM L.....	160 McCord St., Montreal.
1903 Oct. 8.	BISHOP, REGINALD W.....	Owen Sound, Ont.
1903 Oct. 8.	BIXEL, A. W.....	Strathroy, Ont.
1899 Mar. 16.	BLACK, THOMPSON T.....	P.E.I. Ry., Charlottetown, P.E.I.
1903 May 21.	BLACK, DOUGLAS E.....	115 Metcalfe St., Montreal.
1902 Dec. 18.	BLAIR, WILLIAM JOHN	New Liskeard, Ont.
1902 May 22.	BLANCHARD, AUBREY A.....	Dom. Bridge Co., Montreal.
1904 Jan. 14.	BLANCHARD, AUBREY B.....	Bala, Muskoka, Ont.
1902 May 22.	BLANCHET, GUY H.....	Ottawa, Ont.
1902 Apr. 10.	BLANCHET, WILLIAM H.....	Peterborough, Ont.
1903 May 21.	BLUMENTHAL, SAMUEL.....	143 Mansfield St., Montreal.
1903 Oct. 8.	BODWELL, HOWARD L.....	Ingersoll, Ont.
1904 Apl. 14.	BOLGER, EDMUND J.	397 Brock St., Kingston.
1902 Apr. 10.	BORDEN, HENRY P.....	200 Peel St., Montreal.

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1904 Nov. 17.	BOWMAN, A. I. M.	Res. Engr. Off., G. T. Ry., Montreal.
1896 Dec. 17.	BOWMAN, DAVID	Berlin, Ont.
1899 Mar. 16.	BOYD, HUGH HARKNESS	31 St. Mark St., Montreal.
1903 Oct. 8.	BOYER, R. R. C.	Harriston, Ont.
1904 Nov. 17.	BRADT, AUGUSTINE	York, Ont.
1904 Apl. 14.	BRANDON, EDGAR T. J.	Niagara Falls, Ont.
1904 Nov. 17.	BRISTOL, CHARLES F.	186 Versailles St., Montreal.
1904 Apl. 14.	BRUNDIGE, JOHN A.	Box 3, Niagara Falls, N.Y.
1904 Dec. 15.	BRUNNER, GODFREY H.	149 Durocher St., Montreal.
1903 Apr. 23.	BRAY, JOSEPH ULYSSE	Pub. Wks. Dept., Ottawa.
1902 Dec. 18.	BRAYLEY, HAROLD VICTOR	80B Crescent St., Montreal.
1902 May 22.	BROWN, COLLINGWOOD B., JR.	Address wanted.
1903 Apr. 23.	BROWN, FREDERICK B.	153A Mansfield St., Montreal.
1899 Mar. 16.	BUCHANAN, FITZ-HERBERT PRICE	103 Crescent St., Montreal.
1887 Feb. 24.	*Bucke, M. A.*	
1904 Nov. 17.	BUDDEN, HARRY G.	1090 Dorchester St., Montreal.
1902 May 22.	BURCHELL, GEORGE B.	Port Morien, N.S.
1904 Apl. 14.	BURD, JAMES HENRY	Smith's Falls, Ont.
1904 Nov. 17.	BURGESS, EDWARD L.	Surveyor Genl's. Office, Ottawa.
1899 Mar. 16.	BURGOYNE, STANLEY J.	Am. Bridge Co., Trenton, N.J.
1899 Mar. 16.	BURNETT, ARCHIBALD	Address wanted.
1903 Oct. 8.	BURPEE, L.	Gibson, N.B.
1899 Mar. 16.	BURSON, HERBERT A.	Canadian Bullock Co., Montreal.
1899 Mar. 16.	BYERS, ARCHIBALD F.	447 Mount Pleasant Ave., Montreal.
1900 Oct. 11.	BYRNE, THOMAS H.	288 Lisgar St., Ottawa.
1904 Dec. 15.	CADDELL, WILLIAM PERSSE	C. P. Ry., Montreal.
1904 Dec. 15.	CARNES, WILLIAM J.	110 St. Norbert St., Montreal.
1899 Mar. 16.	CAMERON, HUGH DONALD	Box 603, Mont. W. & P. Co., Montreal.
1903 May 21.	CAMERON, JOHN A.	149 Durocher St., Montreal.
1901 Nov. 21.	CAMERON, KENNETH McK.	Can. Nia. Power Co., Niagara Falls, Ont.
1904 Jan. 14.	CAMPBELL, COLIN ST. G. M.	96 St. Famille St., Montreal.
1900 Oct. 11.	CAMPBELL, DUNCAN MCDONALD	Box 373, Sydney, N.S.
1899 Mar. 16.	CAMPBELL, GEO. A. S.	Q. & L. St. John Ry., Quebec.
1900 May 31.	CAMPBELL, JAMES ALEXANDER.	1218 Mission St., San Francisco, Cal.
1903 May 21.	†CAMPBELL, CHARLES M.	Granby Con. M. S. & Pr. Co., Phœnix, B.C.
1904 Jan. 14.	CAMPBELL, JAMES M.	Port Hastings, C.B.

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1899 Dec. 21.	CAMPBELL, NORMAN MCLEOD...	18 Victoria Square, Montreal.
1903 Oct. 8.	CAMPBELL, W. C.....	Keene, Ont.
1901 Nov. 21.	CARTER, DONALD J.....	Box 392, Edmonton, Alta.
1902 May 22.	CAUCHON, JOSEPH E., JR.	124 Edmonton St., Winnipeg, Man.
1904 Jan. 14.	CHAPLIN, CHARLES J.....	478 Athol Avenue, Westmount
1904 Dec. 15.	CHARTON, PIERRE	420 St. Hubert St., Montreal.
1900 May 31.	CHUBBUCK, LEONARD BURTON B.A.Sc. ,.....	516 Kelly St., Wilkinsburg, Pa.
1904 Apl. 14.	CLARKE, FREDERICK F.	Deer Park, Ont.
1903 Oct. 8.	CLARKE, L. O.....	Box 229, North Bay, Ont.
1899 Mar. 16.	CLEMENT, SHELDON B.....	Niagara Falls, Ont.
1902 Apr. 10.	COHEN, HARRIS.....	5 Buckingham Ave., Montreal.
1904 Dec. 15.	CODE, SAMUEL BARBER	Smith's Falls, Ont.
1887 Feb. 24.	*Colquhoun, W. E*.....	
1902 Dec. 18.	COLLINS, RICHARD.....	28 Maple Ave., Montreal.
1904 Jan. 14.	CONGDON, JOHN H.....	Box E., Parry Sound, Ont.
1899 Mar. 16.	COLWILL, THOMAS J.....	Guelph, Ont.
1903 Apr. 23.	CONKLIN, ROSCOE, Y.	107 Henry St., Winnipeg.
1902 Oct. 9.	COOK, A. S.....	Hamilton Cataract Power Co., St. Catharines, Ont.
1903 May 21.	COOKE, C.....	I.C.Ry., Moncton, N.B.
1902 May 22.	COOPER, CLARENCE E.....	40 Macpherson Ave., Toronto.
1903 Apr. 23.	COOPER, CLARENCE E., *Grad. S.P. Sc.*	Cathcart, Ont.
1903 Apl. 23.	CORLESS, CHAS. V., B.Sc.	Victoria Mines, Ont.
1904 Dec. 15.	CORMIER, ERNEST	427 St. Denis St., Montreal.
1899 Mar. 16.	COTÉ, LOUIS E.....	Dept. Marine, Quebec.
1899 Mar. 16.	COTÉ, ONESIPHORE HORACE	The Phoenix Bridge and Iron Works, Montreal.
1902 Oct. 9.	COULSON, JAMES L.....	Copper Cliff, Ont.
1892 Mar. 11.	COURTNEY, REGINALD MORTIMER.	Address wanted.
1898 Mar. 11.	COVERT, J. S.....	156 Lakeview Ave., Glenville, Ohio.
1899 Mar. 6.	COWANS, FREDERICK.....	Address wanted.
1902 Oct. 9.	CRAIG, H. B. R.....	City Engineer, Kingston, Ont.
1904 Jan. 14.	CROPPER, WILLIAM C. M.....	224 University St., Montreal.
1902 Apr. 10.	CROSBY, NORMAN L.	21 Prince Arthur Ave., Toronto.
1904 Apl. 14.	CRUDGE, HARRY J.	215 Prince Arthur St. Montreal.
1904 Nov. 17.	CUMMING, AUSTIN L.	Cornwall, Ont.
1899 Mar. 16.	CURRIE, WM., JUN.....	89 Union Ave., Montreal.
1904 Apl. 14.	D'ABBADIE, CAMILLE, A.	Box 191, Winnipeg, Man.
1899 Mar. 16.	DARGAVEL, JAS. S.....	Elgin, Ont.

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1899 Mar. 16.	DAVIDSON, WM. A.	815 George St., Peterborough, Ont.
1899 Dec. 21.	DAVIES, FREDERICK, DEC.	Box 131, Cornwall, Ont.
1900 Apr.12.	DAVY, HAROLD MORTIMER.	26 Sweetland Ave., Ottawa.
1898 Dec. 22.	DEAN, BERTRAM DODD.	Burgher Ave., West Brighton, Staten Island, N.Y.
1899 Mar. 16.	DENIS, LEOPOLD.	Address wanted.
1894 Mar. 29.	†DENIS, THEOPHILE.	Geological Survey, Ottawa.
1899 Mar. 16.	DENIS, VALMORE.	Dept. Public Works, Ottawa.
1903 Oct. 8.	DEROCHE, ALEX. P.	Napanee, Ont.
1903 Apr. 23.	DESSAULLES, HENRI	St. Hyacinthe, Que.
1902 May 22.	DEYELL, HAROLD J., B.Sc.	Port Hope, Ont.
1904 Apl. 14.	DEY, VICTOR A. G.	Mount Royal Vale, Montreal.
1895 May 23.	DIBBLEE, HARRIE MILES.	Woodstock N.B.
1904 Nov. 17.	DILLABOUGH, JAMES V.	North Williamsburg, Ont.
1904 Jan. 14.	DONALDSON, JOHN M.	80 Wellesley Rd., Croydon, Eng.
1904 Nov. 17.	DOWIE, KENNETH W.	223 Commissioners St., Montreal.
1904 Jan. 14.	†DRYSDALE, WILLIAM F., B.Sc.	7 Grove Place, Schenectady, N.Y.
1899 Mar. 16.	DUBUC, ARTHUR E.	413 Mer. Bk. Bdg., Montreal.
1903 Apr. 23.	DUBUC, J. HENRI	602 Sherbrooke St., Montreal.
1900 Nov. 22.	DUFF, WM. ALEXANDER *Grad. S.P. Sc.*	Canada Bridge Co., Walkerville, Ont.
1904 Nov. 17.	DUNLOP, G. P. G.	912 Sherbrooke St., Montreal.
1903 Apr. 23.	DURLAND, ROYDEN KEITH	McGill University, Montreal.
1904 Jan. 14.	DUTCHER, HOWARD K., B.Sc.	20 Hutchison St., Montreal.
1903 Apr. 23.	EDGAR, JOHN HAMILTON, B.Sc.	380 Mountain St., Montreal.
1904 Nov. 17.	EDWARDS, WILLIAM MILTON, *Grad. S.P. Sc.*	Iroquois, Ont.
1902 Dec. 18.	EDWARDS, WILLIAM MUIR, M.Sc.	66 Mackay St., Montreal.
1902 Apr. 10.	ELLIOT, LAURIE B.	Box 245, Dartmouth, N.S.
1904 Apl. 14.	EVE, ARTHUR STEWART.	990A Sherbrooke St., Montreal.
1898 Dec. 8.	†EWART, GEORGE R.	Kilauea, Kauai, Hawaiian Islands.
1899 Mar. 16.	EWAN, HERBERT M.	Toledo Steel Works, Sheffield, England.
1904 Nov. 17.	FAIRLIE, THOMAS U.	480 Brock St., Kingston, Ont.
1897 Mar. 11.	G†FARMER, J. T.	Coristine Bdg., Montreal.
1903 May 21.	FERGUSON, MELLIS.	Address wanted.
1899 Mar. 16.	FETHERSTONHAUGH EDW'D P.	5 Elgin St., Ottawa.

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1902 May 22.	*Fillmore, Stanley H...*	
1899 Mar. 16.	FINCH, H. J. WADSWORTH.....	1225 Burrard St., Vancouver, B.C.
1904 Nov. 17.	FINDLAY, DELMER C.	74 Victoria St., Montreal.
1899 Mar. 16.	FISET, GEO. EDGAR.....	C. P. R., Montreal
1899 Mar. 16.	FORMAN, ANDREW S.....	1146 Dorchester St, Montreal.
1903 Apr. 23.	†FOREMAN, ALVAH E., B.Sc. ..	137 Bloor St. W., Toronto.
1899 Mar. 16.	FRASER, CHAS. EDWARD.....	153 Lennox Ave., New York.
1899 Dec. 21.	FRASER, J. A.....	L'Orignal, Ont.
1903 Apr. 23.	FRAME, STANLEY H.	c|o Divn. Engr., Trans-Cont. Ry., Winnipeg.
1899 Mar. 16.	FRASER, JAS. WM., M.Sc. ...	Shawinigan Water and Power Co., Montreal.
1899 Mar. 16.	FRASER, JOHN WM., B.Sc. ...	Address wanted.
1902 Dec. 18.	FRECHETTE, HOWELLS, M.Sc. ..	87 Mackay St., Ottawa.
1904 Nov. 17.	FREEMAN, J. R.	Brooklyn, N.S.
1899 Mar. 16.	FRY, DAVID MERNER.....	Bright, Ont.
1902 Dec. 18.	FYSHE, THOMAS M.....	70 McTavish St., Montreal.
1902 Apr. 10.	GAGNE, STANISLAS, *Grad. S.P. Sc.*	59 Home Life Bdg., Toronto.
1899 Mar. 16.	GAGNON ERNEST E.....	25 Melbourne Ave., Westmount.
1898 Mar. 24.	GAGNON, FREDERIC LOUIS	25 Melbourne Ave., Westmount, P.Q.
1904 Jan. 14.	GARIEPY, JOSEPH M. A.	259 Panet St., Montreal.
1904 Nov. 17.	GARNER, ALBERT C.	South Qu'Appelle, Assa., N.W.T.
1904 Nov. 17.	GILLIES, GEORGE A.	McGill University Montreal.
1899 Mar. 16.	GISBORNE, LIONEL L., B.Sc...	Address wanted.
1904 Apl. 14.	GLASSCO, GORDON B.	766 Sherbrooke St., Montreal.
1902 Apr. 10.	GOBEIL, ARTHUR A.....	Address wanted.
1903 May 21.	GRANT, JOHN R.....	155 Sydenham Rd., Kingston.
1904 Apl. 14.	GRANT, LIONEL E. H.	251 Wellesley St., Toronto.
1904 Jan. 14.	GREEY, JOHN W. G., B.Sc. ..	2 Church St., Toronto.
1903 May 21.	GREENLEES, ALEXANDER H....	40 Ridout St., London, Ont.
1895 May 23.	GREIG, ALEX. R.....	Can. Nor. Ry., Winnipeg, Man.
1899 Mar. 16.	GREIR, ARTHUR GORDON, M.Sc.	24 Seymour Ave, Montreal.
1900 Nov. 22.	GROUT, HORACE CLYDE.....	Res. Eng. C.P.Ry., Main. of Way, Toronto.
1904 Dec. 15.	HADLEY, HENRY	1021 Wellington St., Montreal.
1902 Apr. 10.	HAFFNER, HENRY J. A., B.Sc.	c|o J. S. Dennis, Calgary. N.W.T.

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1903 Apr. 23.	HALL, OLIVER, B. Sc.	Washington, Ont.
1904 Nov. 17.	HAMERSLEY, H. ST. G.	Vancouver, B.C.
1899 Mar. 16.	HAMILTON, GEO. MILNE	Peterborough, Ont.
1904 Dec. 15.	HAMILTON, S. WILFRED	132 Mansfield St., Montreal.
1899 Mar. 16.	HAMPSON, E. GREVILLE	302 Peel St., Montreal.
1904 Nov. 17.	HANDLEY, JOHN	128 Slater St., Ottawa.
1896 Dec. 17.	HANDY, EDWARD FRANCIS T.	Emsdale, Ont.
1901 Nov. 21.	HARCOURT, ROBERT H.	Welland, Ont.
1899 Mar. 16.	*Hardy, M. J. Edmond*	
1894 Jan. 4.	†HARE, GEORGE G.	C.P.Ry., Woodstock, N.B.
1902 Oct. 9.	HARRIS, ALAN DALE	263 McLaren St., Ottawa.
1902 Oct. 9.	HARRIS, SPENCER L. DALE	263 McLaren St., Ottawa.
1904 Apl. 14.	HARVEY, JOHN B.	36 Cathcart St., Montreal.
1902 May 22.	HEALY, FRED. E.	Picton, Ont.
1901 Apr. 25.	HEAMAN, J. A.	771 Queen's Ave., London, Ont.
1899 Mar. 16.	HICKEY, JOHN V.	90 Mackay St., Montreal.
1899 Mar. 16.	HIGMAN, ORMOND, JR.	231 McLeod St., Ottawa, Ont.
1904 Nov. 17.	HILL, ERNEST S., *Grad. R.M.C.*	St. Stephen, N.B.
1904 Dec. 15.	†HOGAN, JOHN M., B.Sc.	144 Metcalfe Ave., Westmount
1904 Apl. 14.	HOGG, THOMAS H.	Chippewa, Ont.
1903 Oct. 8.	HORSEY, BURTON T.	251 Wellingston St., Ottawa.
1899 Mar. 16.	HOWARD, RUPERT F.	Lachine, Que.
1903 Oct. 8.	HOYLES, N. W. C.	567 Huron St., Toronto.
1901 Nov. 21.	HUGHES, GARNET B.	Parry Sound, Ont.
1903 Oct. 8.	HURTUBISE, LOUIS	57 Mansfield St., Montreal.
1899 Mar. 16.	HYDE, GEO. TAYLOR	696 Pine Ave., Montreal.
1902 Oct. 9.	IDSARDI, HAROLD	McGill University, Montreal.
1903 Apr. 23.	IRVING, THOMAS C. J., JR.	246 Huron St., Toronto.
1904 Dec. 15.	ISBESTER, COLIN J. F.	Farnham, P.Q.
1899 May 25.	JACKSON, J. HERBERT	Niagara Falls, Ont.
1903 Apr. 23.	JAMES, EDGAR A.	Thornhill, Ont.
1902 May 22.	JENNINGS, GORDON T., B.Sc.	University Crescent, Toronto.
1902 Dec. 18.	JEWETT, F. C.	McGill University, Montreal.
1900 May 31.	JOHNSON, EDW. PRESTON	84 McLaren St., Ottawa.
1900 Oct. 11.	JOHNSON, *(Lieut.)* GORDON B.	Brampton Barracks, Chatham, Eng.
1894 Oct. 11.	JOHNSON, SYDNEY M., B.A.Sc.	Civil and Mining Engineer, Greenwood, B.C.
1902 Apr. 10.	JONES, HAROLD W.	Dept. Marine, Ottawa.

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1902 Dec. 18.	JOSEPH, ABRAHAM P.	McGill University, Montreal.
1902 Dec. 18.	JOST, E. BURTON.	McGill University, Montreal.
1899 Mar. 16.	JUDAH, FREDERICK R.	1212 Dorchester St., Montreal.
1904 Dec. 15.	KEEFER, EDWARD C.	290 Simcoe St., Toronto.
1901 Nov. 21.	KEEFER, THOS. C., (*2nd Lieut. R.E.*)	The Curragh Camp, Ireland.
1904 Jan. 14.	KENNEDY, HENRY CRON.	Hawkesbury, Ont.
1904 Nov. 17.	KENT, VICTOR J.	Fort William, Ont.
1902 May 22.	KEITH, FRASER S., B.Sc.	232 McGill St., Montreal.
1899 Mar. 16.	KERR, ALISON P. R.	484 Athol Ave. Westmount.
1900 Apr. 12.	KILLALY, ALBERT LAURANCE.	Cardinal, Ont.
1894 Jan. 4.	KILLALY, HAMILTON M., B.A.	C. P. Ry., Byng Inlet, Ont.
1903 Oct. 8.	KIMBER, R. A. C.	Dom. Bridge Co., Montreal.
1903 Apr. 23.	KINGSFORD, PIERS	18 St. Joseph St., Toronto.
1901 Apr. 25.	KIRTON, Y DE C.	Poste Restante, Durban, Natal, S. Africa.
1902 Dec. 18.	KYDD, GEORGE	53 Cherrier St., Montreal.
1903 Apr. 23.	LABELLE, JOSEPH	502 St. Denis St., Montreal.
1904 Jan. 14.	LACHAPELLE, JOSEPH D.	Box 407, Sorel, P.Q.
1902 Dec. 18.	LACOUTURE, JOSEPH.	Box 173, Sorel, P.Q.
1902 Apr. 10.	LAMB, FRANCIS M.	Fairview, B.C.
1902 Dec. 18.	LAMB, HARRY M.	296 Prince Arthur St., Montreal.
1902 Dec. 18.	LAMBART, HOWARD F. J., B.Sc.	Vine Lynn, New Edinburgh, Ottawa.
1902 Apr. 10.	LANDRY, PIERRE A., B.Sc.	C/o Judge Landry, Dorchester, N.B.
1904 Apl. 14.	LAWRENCE, WILLIAM DAWSON B. Sc.	34 St. Famille St., Chicago.
1903 Oct. 8.	LEONARD, EDWIN W.	"Oakwood," London, Ont.
1903 Oct. 8.	LEONARD, ELTON I.	602 Queen's Ave., London Ont.
1904 Nov. 17.	LESAGE, ROYAL, B.A. Sc.	146 St. Famille St., Montreal.
1900 Oct. 11.	LINDSAY, WM. BETHUNE.	Dept. Marine and Fisheries, Ottawa.
1904 Nov. 17.	LIVINGSTONE, DOUGLAS	McGill University, Montreal.
1887 Feb. 24.	LOIGNON, A.	24 St. Augustine St., Montreal.
1894 Mar. 29.	LONERGAN, GERALD J., B.A. Sc.	Buckingham, P.Q.
1902 Dec. 18.	LOUDEN, ANDREW C.	503 King St., Ottawa, Ont.
1887 June 25.	*Lough, William H.*	
1899 Mar. 16.	LOWDEN, WARDEN K.	1150 Sherbrooke St., Montreal.
1900 Oct. 11.	LOWE, EDW. HAMILTON.	Address wanted.
1903 Apr. 23.	LYNCH, FRANCIS C. C.	McGill University, Montreal.
1903 May 21.	LEFEBVRE, OLIVER O.	Public Wks. Dept., Ottawa.
1903 Oct. 8.	LUCAS, FREDERICK T.	Hamilton, Ont.
1904 Nov. 17.	LYTLE, FRED H.	606 Huron St., Toronto.

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1903 May 21.	McALLISTER, WILLIAM J.	51 Souvenir St., Montreal.
1904 Apl. 14.	McAVITY, ALLAN G.	3 Queen's Park, Toronto.
1902 Apr. 10.	McCLEAVE, ARTHUR R.	Prov. Engr's. Office, Halifax, N.S.
1904 Nov. 17.	McCONKEY, THOMAS C.	Guelph, Ont.
1900 Oct. 11.	*McConkey, Walter Ross*	
1899 Mar. 16.	McCONNELL, S. BRUCE	C. P. Ry., White River, Ont.
1904 Jan. 14.	McDOUGALL, GEORGE K., B.Sc.	85 Osborne St., Montreal.
1902 Dec. 18.	McINTOSH, ROBERT F.	McGill University, Montreal.
1902 Apr. 10.	McKAY, FREDERICK A., B.Sc.	1123 Dorchester St., Montreal.
1887 Jan. 20.	*McKenzie, C. P.*	
1902 May 22.	McKENZIE, BERTRAM S., B.Sc.	20 Shuter St., Montreal.
1903 Apr. 25.	McKERGOW, CHARLES, M.Sc.	13 Rosemount Avenue, Westmount.
1902 Dec. 18.	McLACHLAN, DUNCAN W.	49 Shuter St., Montreal.
1904 Dec. 15.	McLEAN, DOUGLAS L.	315 Somerset St., Ottawa.
1899 Mar. 16.	McLEAN, WM. B.	Address wanted.
1901 Nov. 21.	McLENNAN, COLIN C.	48 Bengal Pioneers, c/o Grindlay, Groom & Co., Bengal, India.
1899 Mar. 16.	McMASTER, ARTHUR W.	135 Crescent St., Montreal.
1904 Jan. 14.	McPHEE, JAMES McD., B.Sc.	8 Beaver Hall Sq., Montreal.
1904 Apl. 14.	McPHERSON, FRED G.	26 Campbell Rd., Halifax, N.S.
1903 Oct. 8.	MACDONALD, JOHN A.	Hermanville, P.E.I.
1904 Jan. 14.	MacDERMOT, SIDNEY G. F.	101 Hutchison St., Montreal.
1900 Apr. 12.	MACDOUGALL, ALAN COURSOLLES	Pittsburg Redn. Co., New Kensington, Pa.
1903 Oct. 8.	MacGOWAN, ANDREW R.	P.O. Box 364, Moncton, N.B.
1894 Mar. 29.	MacKAY, HENRY M., B.A., B.A.Sc.	664 Gibraltar Bldg., Kansas City, Missouri, U.S.
1904 Apl. 14.	MACK, JASON F.	Moncton, N.B.
1900 Apr. 12.	MacKEEN, RUPERT THOMAS	Can. Gen. Elec. Co., Toronto.
1903 May 21.	MACKENZIE, ALLAN C.	10 Phillips Place, Montreal.
1904 Apl. 14.	MACLEAN, ALISTER	10a Prince Arthur Street, Montreal.
1904 Nov. 17.	MacNAB, JOHN J.	McGill University, Montreal.
1904 Nov. 17.	MACPHAIL, JOHN G.	178 Alfred St., Kingston, Ont.
1897 Mar. 11.	†MACLEAD, GEO. R., B.Sc.,	G. T. R., Montreal.
1902 Dec. 18.	MAHER, WILLIAM R.	Address wanted.
1899 Mar. 16.	MALO, EUCLIDE.	Address wanted.
1904 Nov. 17.	MASSON, PIERRE A.	2742 St. Catherine St., Montreal.
1902 Apr. 10.	MATTHEWS, WILMOT L.	89 St. George St., Toronto.
1897 Mar. 11.	MATTICE, GREGOR LENNOX	Rat Portage, Ont.
1895 Dec. 19.	*Maunsell, E. St. John*	
1902 Oct. 9.	MAXWELL, MARSHALL A.	Easton Pr. Co., Easton, Pa.

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1901 Nov. 21.	MAYNARD, FRANCIS H.	252 Metcalfe St., Ottawa.
1904 Nov. 17.	MEADE, SYDNEY A.	Sherbrooke, P.Q.
1902 Apr. 10.	MELANCON, HENRI.	Address wanted.
1904 Nov. 17.	MEYERSTEIN, WILLIAM C.	24 McGill Coll. Ave., Montreal.
1903 May 21.	MILDER, ALEXANDER J.	Queen's University, Kingston.
1887 Feb. 24.	*Mill, F. X.*	
1899 Mar. 16.	MILLAR, JAMES L. F.	Box 467, Pembroke, Ont.
1902 May 22.	MILLER, ALBERT P.	Glen Miller, Ont.
1899 Mar. 16.	MILLER, ANGUS K.	Address wanted.
1904 Nov. 17.	MILLER, HENRY B.	20 Lorne Ave., Montreal.
1902 Oct. 9.	MILLIDGE, EDWIN R.	North Sydney, N.S.
1889 Mar. 14.	*Mitchell, Geo.*	
1903 Oct. 8.	MOFFAT, FRANK P.	C/o A. Moffatt, Esq., Cranbrook, B.C.
1903 Oct. 8.	MOFFAT, ROLAND.	Dalhousie, N.B.
1899 Mar. 16.	MONTGOMERY, GEORGE A.	15 Hamel St., Quebec.
1895 May 23.	MOODIE, KENNETH, B.A.Sc.	5754 Washington Ave, Chicago, Ill.
1904 Nov. 17.	MOORE, HERBERT H.	Herald Block, Calgary.
1904 Nov. 17.	MORRISON, ARTHUR M.	Dartmouth, N.S.
1904 Jan. 14.	MORRIS, RICHARD V.	G.T.P. Surveys, Winnipeg.
1901 Nov. 21.	MUDIE, J. MAX.	Address wanted.
1889 Feb. 14.	*Murphy, Cornelus Jos.*	
1899 May 25.	MURPHY, J. F.	Marine Dept., Ottawa.
1904 May 10.	MURRAY, ARCHIBALD (*q*)	Cowansville, P.Q.
1904 Apl. 14.	MURPHY, MICHAEL J.	Prov. Engr's. Off., Halifax.
1904 Jan. 14.	NELLES, D. H.	Grimsby, Ont.
1899 Mar. 16.	NELSON, GEORGE J.	81 Britannia St., Montreal.
1897 Dec. 9.	NEWCOMBE, A. B.	Lakeville, Kings Co., N.S.
1902 Apr. 10.	NEWTON, SAMUEL R.	P.O. Box 552 Sherbrooke, P.Q.
1904 Nov. 17.	NEWLANDS, JOHN ERIC	136 Mansfield St., Montreal.
1904 Nov. 17.	NORMANDEAU, EMILE D.	189 Queen St., Ottawa.
1904 Jan. 14.	O'CONNOR, JOHN E. L.	Parkbeg, Assa.
1894 Mar. 29.	OGILVIE, WM. M.	342 Lyon St., Ottawa, Ont.
1899 Mar. 16.	O'SULLIVAN, OWEN.	Geological Survey, Ottawa.
1903 Oct. 8.	OSLER, S. H.	McGill University, Montreal.
1901 Nov. 21.	OXLEY, JAMES M.	34 Huntley St., Toronto.
1899 Mar. 16.	PALMER, ERNEST E.	Toronto Type Foundry, Toronto.

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1898 Mar. 24.	PARENT, JAMES HECTOR	Public Wks. Dept., Ottawa.
1898 Mar. 24.	PARIZEAU, HENRI D.	Dept. Public Works, Ottawa.
1904 Jan. 14.	†PARLEE, NORMAN W.	Dillsburg, Penn.
1899 Mar. 16.	PATERSON, CHARLES S., M.Sc.	86 College St., Calcutta, India.
1900 Oct. 11.	PATTERSON, FRANK ELLIOTT, B.Sc.	Cardinal, Ont.
1904 Jan. 14.	PEASLEE, ALEXANDER S. L.	149 Durocher St., Montreal.
1903 Apr. 23.	PEDEN, ALEXANDER, JR.	Dom. Bridge Co., Montreal.
1904 Apl. 14.	PEDEN, FRANK, B.Sc.	92 Park Ave., Montreal.
1900 Oct. 11.	PENSE, EDW. HERBERT	49 King St., Kingston, Ont.
1899 Mar. 16.	*Percy, H. Meredith*	
1904 Nov. 17.	PETERS, FREDERICK H.	London, Ont.
1904 Nov. 17.	PHILLIPS, ARCHIBALD McE.	Haverley St., Ottawa.
1903 Apr. 23.	PICKARD, HERBERT G.	Exeter, Ont.
1904 Jan. 14.	POPE, HARRY B.	160 McCord St., Montreal.
1904 Jan. 14.	PORCHERON, ALPHONSE D.	Shawinigan Falls, P.Q.
1903 Oct. 8.	PORTEOUS, JAMES C. E.	Address wanted.
1902 Dec. 18.	PORTER, JOHN W.	C. P. R., Walkerton, Ont.
1904 Dec. 15.	POTTER, ROBERT	106 Bagot St. Kingston.
1903 Apr. 23.	PREFONTAINE, ROLLAND	318 Sherbrooke St., Montreal.
1902 Apr. 10.	PRESTON, JOSEPH H.	94 Park Avenue, Montreal.
1904 Apl. 14.	PRICE, HERBERT L.	766 Sherbrooke St., Montreal.
1899 Mar. 16.	PROCTOR, GEORGE S.	Address wanted.
1904 Nov. 17.	PUTNAM, ALFRED A.	40 S. Park St., Halifax, N.S.
1899 Mar. 16.	PYKE, GORDON McT.	1117 Dorchester St., Montreal.
1903 Oct. 8.	RAMSAY, COLIN P.	Shawinigan Falls, P.Q.
1904 Apl. 14.	REDPATH, WILLIAM	Ontario Ave., Montreal.
1894 Dec. 20.	REID, ROBT. G., JUN.	275 Drummond St., Montreal.
1894 Mar. 29.	†REINHARDT, CARL.	Reinhardt Brewery, Montreal.
1896 June 18.	RENWICK, HALIBURTON PAUL.	Box 594, Rossland, B.C.
1904 Jan. 14.	RICHARDS, CLARKE C., B.Sc.	Address wanted.
1900 Oct. 11.	RIDDELL, JOHN A.	908 Sherbrooke St., Montreal.
1904 Jan. 14.	RITCHIE, ALAN B.	149 Durocher St., Montreal.
1904 Nov. 17.	ROBERTS, ARTHUR R.	200 Centre St., Swisvale Stn., Pittsburg, Pa.
1904 Jan. 14.	ROBERTSON, JOHN F., JR., M.Sc.	788 Palace St., Montreal.
1895 May 23.	ROBINS, SAMPSON P., B.A.Sc.	513 Notre Dame St., Montreal.
1904 Dec. 15.	ROBATAILLE, JOSEPH	Ville St. Laurent, P.Q.
1902 Dec. 18.	ROGER, ALEC.	Topographical Survey, Ottawa.
1904 Jan. 14.	ROGERS, HENRY G.	McGill University, Montreal.
1897 Mar. 11.	RUSSELL, A. MONTGOMERY.	469 Guy St., Montreal.
1899 Mar. 16.	RUST, HENRY P., B.A. Sc.	Elec. Dev .Co., Niagara Falls, Ont.

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1904 Apl. 14.	SAUER, MAX V.	Box 312, Niagara Falls South, Ont.
1899 Mar. 17.	SCHWITZER, THOMAS H., B.Sc.	456 Victoria Ave., Montreal.
1904 Jan. 14.	SCOTT, GEORGE W., B.Sc.	2336 Harris Ave., East Norwood, Ohio.
1904 Jan. 14.	SEARS, JOHN	148 Earl St., Kingston, Ont.
1904 Jan. 14.	SHARPE, ALPHONSO LESTER	118 Durocher St., Montreal.
1904 Jan. 14.	SHARPE, G. P.	McGill University, Montreal.
1904 Nov. 17.	SHAVER, PETER A.	Grantley, Ont.
1899 Mar. 16.	SHAW, JOHN A.	60 St. Luke St., Montreal.
1903 Apr. 23.	SHEHYN, AUGUSTE RÉAL	Three Rivers, P.Q.
1899 Mar. 16.	SHEPHERD, HENRY LAWRENCE, B.Sc.	Post Office, Brockville, Ont.
1904 Nov. 17.	SHEPLEY, JOSEPH D.	Leamington, Ont.
1903 Oct. 8.	SHERWOOD, HENRY L.	C. P. Ry., Byng Inlet, Ont.
1904 Nov. 17.	SILLS, JOHN H.	Address wanted.
1899 Mar. 16.	SIMS, HENRY B.	Asst. Engr. O.N. & W. Ry., Union Stn., Ottawa.
1904 Nov. 17.	SINCLAIR, DUNCAN	Stratford Station, Ont.
1904 Nov. 17.	SINGERS, GEORGE	Asst. Chief Egr's. Off., C.P. Ry., Winnipeg, Man.
1899 Mar. 16.	SISE, PAUL F., B.Sc.	898 Sherbrooke St., Montreal.
1890 May 20.	*Smart, John Alder*	
1904 Dec. 15.	SLATER, NICHOLAS J., *Grad. S.P. Sc.*	193 Sparks St., Ottawa.
1903 Apr. 23.	SMITH, JAMES H., *Grad. S.P. Sc.*	c/o J. L. Morris, Pembroke, Ont.
1899 Mar. 16.	SMITH, GEORGE B.	37 St. Mark St., Montreal.
1904 Jan. 14.	SMITH, SAMUEL W.	Box 2259, Montreal.
1904 Nov. 17.	SMITH, RICHARD H.	Box 153, Sydney, N.S.
1901 Nov. 21.	SPARROW, WALTER F.	1709 Notre Dame St., Montreal.
1904 Jan. 14.	SPROULE, GORDON ST. G.	106B. Stanley St., Montreal.
1893 May 18.	SQUIRE, RICHARD H., B.A.Sc.	51 George St., Brantford. Ont.
1904 Nov. 17.	SQUIRE, RICHARD L.	79 Division St., Kingston Ont.
1901 Nov. 21.	STEWART, ATHOL.	Fredericton, N.B.
1898 Mar. 24.	ST GEORGE, HENRY LUXEMORE.	2744 St. Catherine St., Montreal.
1903 May 21.	STUART, CHARLES W.	Can. Pac. Ry., Winnipeg, Man.
1898 May 10.	STRICKLAND, T. P.	51 Phillips St., Sydney, N.S. W., Australia.
1894 Oct. 11.	SULLIVAN, EDWARD A.	Address wanted.
1904 Jan. 14.	SULLIVAN, MICHAEL H., B.Sc.	104 Metcalfe St., Ottawa.
1899 Mar. 16.	SURVEYER, ARTHUR.	347 Lagauchetiere St., Montreal.
1902 Dec. 18.	SUTHERLAND, CHARLES H.	704 Sherbrooke St., Montreal.

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1898 Dec. 8.	SYER, WILLIAM E.	Address wanted.
1901 Jan. 17.	SYLVAIN, JOHN.	City Engineer's Office, Ottawa.
1904 Apl. 14.	TAPLEY, ALEXANDER GIBSON.	Moncton, N.B.
1904 Jan. 14.	TAYLOR, REGINALD F., B.Sc.	264 Wood Ave., Westmount.
1904 Apl. 14.	THORNE, STUART M.	Niagara Falls Centre, Ont.
1899 Dec. 21.	TILLEY, VINCENT D.	Dept. Rys. and Canals, Ottawa.
1904 Nov. 17.	TOOKER, GUY	Loco. & Machine Co., Montreal.
1902 May 22.	TOOKER, NOEL L.	22 Frontenac St., Kingston, Ont.
1904 Nov. 17.	TOWNSEND, DAVID T.	Woodstock, Ont.
1903 Apr. 23.	TREMBLAY, ALTHÉOD.	C.P.Ry., Montreal.
1904 Nov. 17.	TRIMBLE, ARTHUR V.	91 Dundas St., Toronto.
1902 Oct. 9.	TRIMMINGHAM, CHARLES L.	McGill University, Montreal.
1903 Oct. 8.	TROTTER, H. L.	St. Johns, P.Q.
1902 Dec. 18.	VANASSE, FABIEN, JR.	724 St. Hubert St., Montreal.
1899 Mar. 16.	VAN HORNE, RICHARD B., B.Sc.	917 Sherbrooke St., Montreal.
1903 Oct. 8.	VAN TUYL, LOUIS G.	77 Gloucester St., Ottawa.
1904 Nov. 17.	VANSITTART, GEORGE E.	71 Sussex Ave., Toronto.
1903 Oct. 8.	WALDRON, STANLEY M.	80 Barrie St., Kingston, Ont.
1904 Nov. 17.	WALKER, HORACE, B.A. Sc.	Cornwall, Ont.
1899 Mar. 16.	WALKER, FRANK W.	Address wanted.
1900 Apr. 12.	WALKER, JOHN PHILIP.	91 Mance St., Montreal.
1903 Apr. 23.	WATEROUS, LOGAN M.	Brantford, Ont.
1899 May 25.	WELDON, ERNEST ALBERT, *Grad. S.P. Sc.*	Winnipeg Hotel, Winnipeg, Man.
1904 Apl. 14.	WEBSTER, GEORGE B., B.Sc.	267 University St., Montreal.
1899 Mar. 16.	WENGER, EDGAR I., B.Sc.	Westinghouse Co., Pittsburg, Pa.
1902 Dec. 18.	WHEATON, H. ASHLEY.	McGill University, Montreal.
1902 Dec. 18.	WHEATON, ISAAC.	McGill University, Montreal.
1899 Mar. 16.	WHITE, FRANK HERBERT.	Care of American Linde Refrigeration Co., 45 Broadway, New York.
1899 Mar. 16.	WHITE, GERALD V.	Pembroke, Ont.
1899 Mar. 16.	WHITLEY, HERBERT A.	288 Stanley St., Montreal.
1899 Mar. 16.	WHYTE, JOHN S.	Glace Bay, C.B.
1902 Oct. 9.	WILGOR, WILLIAM P.	Trans.-Cont. Ry., Cobourg, Ont.
1904 Jan. 14.	WILKES, FREDERICK C. D., B.Sc.	Brantford, Ont.
1904 Nov. 17.	WILSON, ALEX. THOMPSON	I.C. Ry., Moncton, N.B.

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1902 Apr. 10.	WILSON, JOSEPH L.	Salisbury, N.B.,
1903 Oct. 8.	WILSON, FREDERICK P.	Box 229, North Bay, Ont.
1904 Jan. 14.	WILSON, W. DOUGLAS, B.Sc.	Apartado 52, Oaxaco, Mexico.
1900 Apr. 12.	WISE, FRED. AYSHFORD.	Kirkfield, Ont.
1902 May 22.	WRIGHT, CLIFTON H.	38 McGill Coll. Avenue, Montreal.
1903 Oct. 8.	WRIGHT, GORDON B.	Hull, P.Q.
1904 Apl. 14.	WYNN, JOHN G. M.	Niagara Falls, Ont.
1899 Mar. 16.	YORSTON, LOUIS, B.Sc.	3 Thistle Terrace, Montreal.
1900 Oct. 11.	YOUNG, WALTER BEATTY.	Selkirk, Man.
1899 Mar. 16.	YOUNG, WILLIAM McGEE, B.Sc.	144 Milton St., Montreal.
1903 May 21.	YOUNG, CLARENCE R., *Grad. S.P. Sc.*	100 Hazleton Ave., Toronto.

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LIST OF MEMBERS ELECTED 16TH MARCH, 1905.

MEMBERS.

COCHRANE, JOHN BRAY	R. M. College, Kingston, Ont.
DUPONT, V. HECTOR, C.E., *(Montreal Pol. Sc.)*	35 St. James St., Montreal.
FRASER, EDWIN STANTON	V. & S. W. Ry., Bristol, Tenn.
HARDMAN, JOHN ERNEST	1018 Sherbrooke St., Montreal.
HARRINGTON, JOHN LYLE, B.A., B.Sc.	Loco. & Machine Co., Montreal.
PEACOCK, FRANCIS TOY	Canada Life Building, Montreal.

ASSOCIATE MEMBERS.

BURPEE, DAVID WILLIAMS	P. O. Box 42, Fredericton, N.B.
CAIRNIE, LORNE MCDOUGALL, B.A.	396 St. Antoine St., Montreal.
DOWSON, ERASMUS, C. H	98 Ste. Famille St., Montreal.
FRASER, ALAN TRAVERS	175 Cooper St., Ottawa.
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